Z. Phys. A 356, 239–240 (1996)

ZEITSCHRIFT
FÜR PHYSIK A

Short note

In-beam study of ^{102}Sn

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Received: 13 September
Communicated by B. Herskind

Abstract. Excited states in ^{102}Sn have been identified for the first time, in an in-beam γ-ray spectroscopic experiment. Two γ-ray transitions with energies 1472 and 497 keV following the decay of the seniority 6^+ isomer with $t_{1/2}$ = 1.0(5) μs were unambiguously assigned to ^{102}Sn. Due to the very low cross section of about 2 μb for producing ^{102}Sn in the reaction ^{50}Cr(^{58}Ni,1α2n), a highly selective detector setup utilizing NORDBALL ancillary detectors and a recoil catcher device was used. High γ-ray detection efficiency was achieved with two EUROBALL Ge cluster detectors.

PACS: 21.10.Tg; 23.20.Lv; 25.70.Gh; 27.60.+j

In order to extend our current knowledge of the structure of nuclei in the ^{100}Sn region we have recently performed two experiments aiming at studies of excited states in the two proton-hole nucleus ^{98}Cd [1,2] and in its two neutron-particle counterpart ^{102}Sn. This work reports on our results concerning ^{102}Sn.

The experiment was performed at the Tandem Accelerator Laboratory of the Niels Bohr Institute in Denmark. A 225 MeV ^{58}Ni beam was used to bombard a 1 mg/cm^2 thick ^{50}Cr target enriched to 99.0 %. Since there were indications for the existence of a long lived isomeric state in ^{102}Sn [3], a special detector setup made of two parts, was assembled. The first part, which was placed around the target, consisted of a 4π Silicon ball with 31 elements, a 2π Neutron wall with 15 elements and 5 large BaF_2 detectors. The ancillary detectors were used for identification of the reaction channel and for obtaining a precise time reference signal for each event. The second part of the setup consisted of an exchangeable recoil catcher foil placed 60 cm downstream from the target and surrounded by two EUROBALL Ge cluster detectors. Only γ-ray decays, that occurred after the recoils were stopped in the catcher foil, were detected. The flight time of the recoils was about 50 ns. Additional experimental details are given in [1].

A part of a 1α2n gated γ-ray spectrum is shown in Fig. 1b. A γ-ray line at 1472 keV can be seen among other lines in this spectrum. This line is also present in the 1α1n gated spectrum (Fig. 1a) due to detection of only one of the two neutrons, but absent in the 1p1α1n (Fig. 1c) and 2α1n (Fig. 1d) gated spectra. Thus, the 1472 keV line does not belong to a reaction channel with a proton multiplicity > 0 nor to one with an α-particle multiplicity > 1. The intensity ratio of the 1472 keV line in the 1α2n and the 1α1n gated spectra has been compared to the intensity ratio of transitions in ^{100}Cd, which was populated in the 2p1α2n channel. The result indicates that the 1472 KeV line is in a nucleus populated in a reaction with neutron multiplicity 2. Therefore, we assign this γ ray to the 1α2n reaction channel. A considerable build up of carbon and oxygen on the target took place during the experiment. By studying both the intensity of the 1472 keV γ ray as a function of beam time as well as the angular distribution of the coincident α particle it was found that this γ-ray line is not due to reactions on C or O but originates from reactions on ^{50}Cr. Thus we can unambiguously assign it to ^{102}Sn. The cross section for the reaction leading to ^{102}Sn was estimated to be about 2 μb [1].

In addition to the 1472 keV γ ray, we found in the 1α2n gated spectrum a γ-ray line at 497 keV that behaved in the

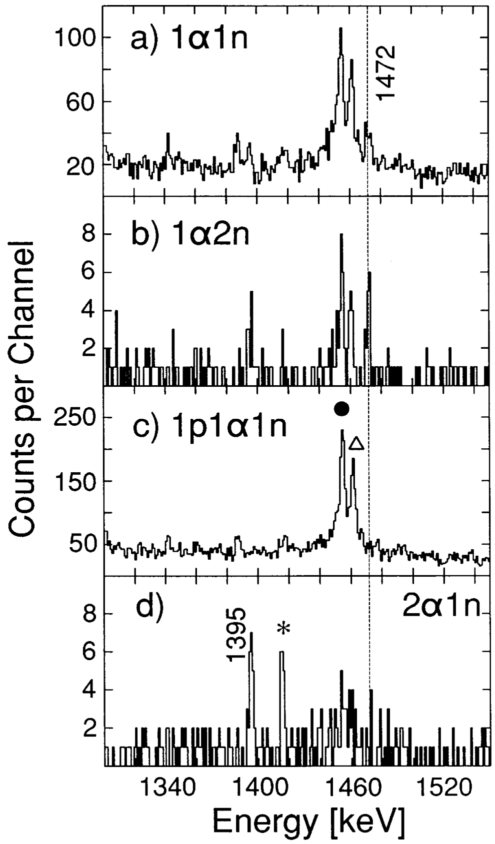

Fig. 1a–d. Parts of particle gated γ-ray spectra, **a** 1α1n gated, **b** 1α2n gated, **c** 1p1α1n gated and **d** 2α1n gated spectrum. The 1472 keV γ ray assigned to ^{102}Sn (see text) is present in **a** and **b** but not in **c** and **d**. The γ ray at 1395 keV belonging to ^{98}Cd is labeled in **d**. The γ rays marked with symbols belong to: $\bullet$ ^{58}Ni, $\triangle$ ^{40}K and $*$ ^{96}Pd

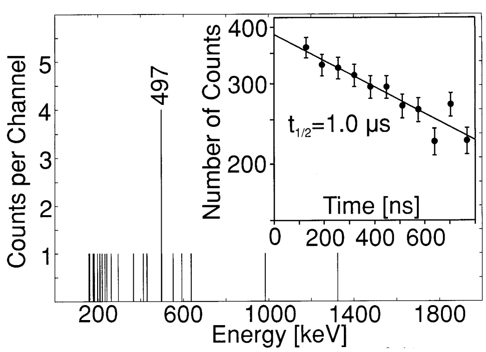

Fig. 2. Spectrum obtained by gating on the 1472 keV γ ray in the sum of the 1α2n, 1α1n and 2n gated γ-γ matrices. Sum of the time spectra of the 1472 keV and 497 keV γ rays gated by 1α2n, 1α1n, 2n or 1n is shown as an insert

same way as the 1472 keV line in the particle gated spectra. These two γ rays are in mutual coincidence, which can be seen in Fig. 2. The 1472 keV and the 497 keV γ rays both follow the decay of a long lived isomeric state in ^{102}Sn. The sum of the time spectra of both γ rays is shown as an insert in Fig. 2. The fit to the points gives a half life of 1.0(1) μs. An estimated systematic error of 0.5 μs is added to the error in the half life due to the uncertainty in the background subtraction.

Recent shell model calculations [4–6] predict the lowest 6^+ state in ^{102}Sn to be isomeric and to have a rather pure aligned $\nu d_{5/2} g_{7/2}$ configuration. The assignment of $J^\pi = 6^+$ to the isomeric state is supported by our experimental results, although we have identified only two transitions below the isomer. It is, however, very probable that a low energy transition between the 6^+ and 4^+ states was not observed due to low statistics and due to the internal conversion of such a low energy E2 transition. If the B(E2;$6^+ \rightarrow 4^+$) value was the same in ^{102}Sn as in ^{104}Sn, i.e. 4 W.u. [7], the energy of the $6^+ \rightarrow 4^+$ transition would be with the measured half life in ^{102}Sn about 40 keV. The conversion coefficient for such a low energy E2 transition is about 45, which makes it very probable that the transition was not observed in the present work.

In view of the above discussion we assign the 1472 keV γ ray as due to the $2^+ \rightarrow 0^+$ transition and the 497 keV γ ray as due to the $4^+ \rightarrow 2^+$ transition. The excitation energy of the 2^+ state is about 200 keV higher in ^{102}Sn than in ^{104}Sn and in the heavier even mass Sn isotopes where it is fairly constant. Such a trend was also observed close to the double shell closure in the Ni isotopes. It is also corroborated by empirical shell model calculations [5,6], which predict the lowest 2^+ state at about 1.7 MeV, whereas a large-scale shell model calculation with a realistic effective interaction [4] predicts it to be at 1.3 MeV. The empirical shell model calculations also predict the lowest 4^+ and 6^+ states at an excitation energy of about 2 MeV while in the large-scale shell model calculation these states lie about 400 keV lower. The relatively big drop of about 200 keV in the excitation energy of the lowest 6^+ state going from ^{104}Sn to ^{102}Sn is therefore well corroborated by the shell model calculations.

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