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Beta-decay spectroscopy of ^{103,105}Sn

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Abstract. Experimental and theoretical β-decay properties of ^{103,105}Sn are discussed.

PACS. 23.40.-s β decay; double β decay; electron and muon capture – 27.60.+j $90 \leq A \leq 149$ – 21.10.Tg Lifetimes – 21.10.-k Properties of nuclei; nuclear energy levels

Experimental data on the structure of nuclei in the ^{100}Sn region allow one to test predictions of the nuclear shell model. Two complementary setups were used to investigate the decay of ^{103,105}Sn (for the results on even-even tin isotopes see [1]), namely an array of high-resolution silicon and germanium detectors as well as a total-absorption spectrometer (TAS) [2]. The experiment was performed at the GSI on-line mass separator. ^{103,105}Sn were produced in fusion-evaporation reactions, namely ^{50}Cr(^{58}Ni, αn)^{103}Sn and ^{50}Cr(^{58}Ni, 2p1n)^{105}Sn. A 5 MeV/u ^{58}Ni beam of about 40 particle-nA from the linear accelerator UNILAC impinged on an enriched ^{50}Cr target (3–4 mg/cm^2, enrichment 97%). A FEBIAD-B3C ion source with carbon, niobium and ZrO_2 catchers, respectively, was used. High chemical selectivity for tin was achieved by adding CS_2 vapour to the ion source [3,4]. Using this technique about 60% of the tin ion-output is shifted to the SnS^+ molecular side-band, thus suppressing strongly the In, Cd, Ag, and Pd isobaric contaminants. After ionization, acceleration to 55 keV, and mass separation in a magnetic sector field, the $A = 103 + 32$ ($A = 105 + 32$) ions were directed to the high-resolution setup or to the TAS. The production yields of ^{103,105}Sn are given in ref. [1].

The β-delayed γ-rays of ^{103}Sn were measured for the first time with a high-resolution gamma array. An array consisting of three silicon detectors and 17 germanium crystals (FZR-Cluster and two GSI VEGA SuperClover detectors) allowed for the detection of β-γ and β-γ-γ coincidences. In addition to the transitions from the 1078 keV ($11/2^+$) and 1273 keV ($13/2^+$) states known from in-beam spectroscopy [5], 20 new γ transitions in ^{103}In were identified. The half-life of ^{103}Sn was determined to be 7.0(3) s in agreement with a previous measurement [6]. The level scheme of the daughter nucleus ^{103}In, shown in fig. 1, was constructed by using the β-γ-γ coincidence data (for more details, see in [7]). It was impossible to make reliable spin-parity assignment from the experimental data. The tentative spin and parity assignment for low-lying ^{103}In levels stem from a comparison of experimental excitation energies with shell model predictions. However, this method does not yield unambiguous results for high-lying ^{103}In states. Moreover, the apparent feeding of ^{103}In levels by β-decay of the ($5/2^+$) ground state of ^{103}Sn cannot be used for spin and parity assignment either. This is due to the fact that the TAS data show that almost all levels are not directly fed in β-decay but by γ transitions from high-lying states.

The β-decay in the ^{100}Sn region is dominated by the allowed Gamow-Teller (GT) $\pi g_{9/2} \to \nu g_{7/2}$ transition, with

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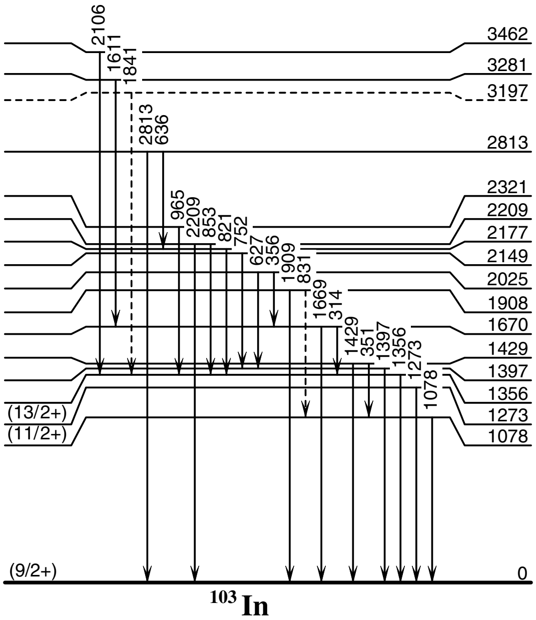

Fig. 1. Partial level scheme of ^{103}In obtained from ^{103}Sn β-decay high-resolution measurements.

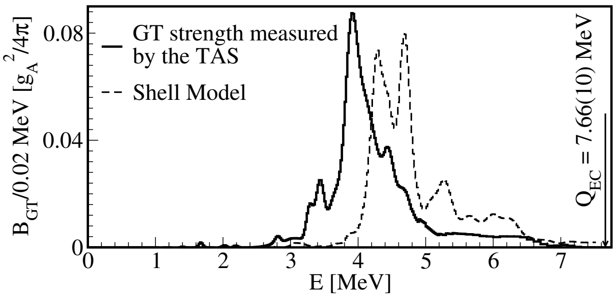

Fig. 2. GT strength distribution for ^{103}Sn obtained from the TAS measurement (solid line) and resulting from the shell model calculations (dashed line). The theoretical distribution was normalized to the summed experimental $B_{\rm GT}$.

almost all GT strength ($B_{\rm GT}$) lying within the respective $Q_{\rm EC}$ windows. The GT strength distributions of ^{103,105}Sn were measured using the TAS, being most appropriate to determine β feeding of weakly populated high-lying states in the daughter nucleus. As the total absorption efficiency of the TAS-differs from 1, the response function of the TAS for de-exciting γ cascades differs from a δ-function and is obtained through a Monte Carlo simulation. The latter requires as input information the level scheme of the daughter nucleus, in this case ^{103}In or ^{105}In. For the case of ^{103}Sn the scheme shown in fig. 1 was used for the analysis of the TAS data. For ^{105}Sn, the decay scheme was taken from [8].

Figure 2 shows a comparison of experimental and theoretical GT strength distributions for ^{103}Sn. The shape of the experimental distribution is dominated by a resonance structure extending between 3.5 and 5 MeV excitation energy in ^{103}In. This decay characteristics are interpreted as the GT decay of the even-even core to the three-quasiparticle configurations. The theoretical $B_{\rm GT}$ distribution, shown in fig. 2, is resulting from a shell model calculation performed in the $\pi(1g_{9/2}, 2p_{1/2})^{12}$-$\nu(1g_{7/2}, 2d_{5/2}, 2d_{3/2}, 3s_{1/2}, 1h_{11/2})^3$ model space [9,10] and normalized to the summed experimental GT strength ($\sum B_{\rm GT}^{\rm exp}$). The theoretical distribution qualitatively agrees with general shape of the measured GT strength but it is shifted by 400 keV towards higher excitation energies.

Table 1. Experimental and calculated $\sum B_{\rm GT}$ $[g_A^2/4\pi]$ for ^{103,105}Sn. The respective occupancies of neutron $\nu g_{7/2}$ orbital ($N_{7/2}$) and hindrance factors (h) are also given.

	$\sum B_{\rm GT}^{\rm exp}$	$N_{7/2}$	$\sum B_{\rm GT}^{\rm SM}$	h
^{103}Sn	3.5(5)	1.26	15.0	4.3(6)
^{105}Sn	2.9(4)	1.95	13.4	4.6(6)

Table 1 shows the resulting $\sum B_{\rm GT}^{\rm exp}$ values, given in units of $g_A^2/4\pi$. This evaluation for ^{103}Sn and ^{105}Sn was based on $Q_{\rm EC}$ values of 7.66(10) and 6.23(8) MeV [7] and half-lives of 7.0(3) s and previously measured 34(1) s [8], respectively. In table 1 the $\sum B_{\rm GT}^{\rm exp}$ results are compared with the estimate of the modified independent-particle shell model $\sum B_{\rm GT}^{\rm SM} = \frac{N_{9/2}}{10}(1 - \frac{N_{7/2}}{8})B_{\rm GT}^0$. Here $N_{9/2}$ denotes the number of protons filling the $\pi g_{9/2}$ orbital, $N_{7/2}$ the corresponding value for the $\nu g_{7/2}$ orbital, and $B_{\rm GT}^0 = 4\ell(2j_> + 1)/(2\ell+1) = 160/9$ for the $\pi g_{9/2} \to \nu g_{7/2}$ GT transition. The occupancies $N_{7/2}$ were deduced from wave functions of the $5/2^+$ ground states obtained from the shell model calculations mentioned above. The resulting $N_{7/2}$ values for ^{103}Sn and ^{105}Sn are 1.26 and 1.95, respectively. Because of the model space restriction, the $N_{9/2}$ value is 10 for both nuclei. To check the accuracy of such an estimate the $\sum B_{\rm GT}^{\rm SM}$ value for ^{103}Sn was compared with that obtained by the shell model calculation mentioned above, yielding good agreement. However, the calculated total GT strength is significantly larger than the measured $\sum B_{\rm GT}^{\rm exp}$ values. The hindrance factors h, defined as $\sum B_{\rm GT}^{\rm SM} / \sum B_{\rm GT}^{\rm exp}$ ratio, amounts to 4.3(6) and 4.6(6) for ^{103}Sn and ^{105}Sn, respectively. In summary, measurements performed with the use of the TAS provided qualitatively new data on the GT strength distribution for ^{103,105}Sn. The results obtained constitute a solid ground for the test of theoretical calculations and call for more advanced shell model calculations.

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