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THE NEW BETA-DELAYED PROTON PRECURSORS ^{103}Sn AND ^{105}Sn

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ABSTRACT

Using $^{58}\text{Ni} + ^{50}\text{Cr}$ and $^{58}\text{Ni} + ^{54}\text{Fe}$ reactions and on-line mass separation, the new isotopes ^{103}Sn and ^{105}Sn with half-lives of 7 ± 3 s and 31 ± 6 s, respectively, were identified via their beta-delayed proton decays. The relative yields and the possibility of reaching ^{101}Sn are discussed.

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3. Experimental Results

The energy spectra of beta-delayed protons measured at mass 105 and 103 and assigned to the precursors ^{105}Sn and ^{103}Sn , respectively, are shown in Figs. 2 and 3 together with half-life analyses. Data were accumulated both from the ^{50}Cr and the ^{54}Fe target with about 1.4 h counting time for each. The counting rates for ^{105}Sn and ^{103}Sn amounted to 3.3 min^{-1} and 1.0 min^{-1} , respectively, for the ^{50}Cr target, whereas the source strengths normalized to the same ^{58}Ni beam current were higher by 10% and lower by a factor of 2, respectively, for the ^{54}Fe target. Fifteen beta-delayed proton events were found for mass 101 by measuring this activity at an in-beam telescope detector simultaneously to the experiments mentioned above.

As far as the assignment of the observed beta-delayed proton activities to ^{105}Sn and ^{103}Sn is concerned, the mass number is given unambiguously by the magnetic separation. Higher-Z isobaric nuclei are excluded on the basis of systematics for production cross sections and/or of energy systematics for beta-delayed proton emission. The elemental assignment with respect to lower-Z isobaric nuclei is easily made since their known half-lives /7/ differ distinctly from the values of $31 \pm 6 \text{ s}$ and $7 \pm 3 \text{ s}$ measured for ^{105}Sn and ^{103}Sn , respectively. The few proton events observed at mass 101 cannot yet be assigned with certainty to the decay of ^{101}Sn , even though this assignment is the most probable one. More experimental data, in particular on the half-lives of ^{101}Sn and ^{101}In , are needed to clarify the present ambiguity.

4. Discussion

The measured beta-delayed proton data can be compared with results from calculations using a statistical model /8,9/. Ground-state spin and parity 1^π of $5/2^+$ for the initial nuclei and a constant beta-strength function were assumed. Using recent mass measurements /10/ and extrapolating the trend of their deviations from model-predictions, we obtained values of Q_{EC}/S_p (in MeV) for the precursors ^{105}Sn , ^{103}Sn and ^{101}Sn of 5.98/2.79, 7.39/2.04 and 8.65/1.27, respectively. It is interesting to note that the $Q_{\text{EC}}-S_p$ value was known from mass measurements /10/ to be $3.19 \pm 0.13 \text{ keV}$ for the precursor ^{105}Sn (see fig. 2) prior to its identification. The calculations of the beta-delayed proton spectra can at present only be considered as a first approximation, and more complete experimental data such as better statistics in the proton spectra and branching ratios for the total beta-delayed proton decay and its feeding of excited states in the final cadmium nuclei are clearly needed. The measured gross shape of the beta-delayed proton spectra, including the overall shift towards higher proton energies in going from ^{105}Sn to ^{103}Sn , is reproduced by the model calculations. In judging the measured energy spectra one should take into account, that there is a detection threshold in the energy range of 1.5 to 2 MeV corresponding to the stopping of protons in the ΔE detector. As far as beta decay is concerned, it is interesting to notice the qualitative agreement between the half-lives

measured for ^{103}Sn and ^{105}Sn and the values of 5 s and 30 s, respectively, predicted by the gross theory of beta decay /11/.

In comparing the proton rates measured for the ^{50}Cr and ^{54}Fe targets with results from evaporation calculations (see Fig. 1), one notes that at least the trends in producing ^{103}Sn and ^{105}Sn are correctly described by the code within a factor of 2. Quantitative conclusions are excluded at present as an experimental production cross section could only be determined from our measurements if the on-line overall efficiencies and the branching ratios for beta-delayed proton emission were known. Qualitatively, however, one can use calculated production cross sections, measured proton rates and calculated branching ratios P_p for beta-delayed proton emission in order to derive overall efficiencies η (see table 1). As the resulting η values and their dependence on half-life are in accordance with the general trend emerging from earlier measurements /6,12/, the evaporation code and the beta-delayed proton calculations taken together seem to give a proper description. The difficulty in studying even more neutron-deficient tin isotopes such as the doubly magic nucleus $^{100}_{50}\text{Sn}$ becomes evident considering the cross section of about 8 μb calculated for the production of ^{101}Sn in the $^{50}\text{Cr}(^{58}\text{Ni}, 2p5n)$ reaction.

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Precursor	Half-life (s)		$\eta \times P_p$	P_p from statistical model calculations	η
	measured	calculated /11/			
^{105}Sn	31 ± 6	30	6×10^{-6}	1.4×10^{-4}	4×10^{-2}
^{103}Sn	7 ± 3	5	6×10^{-5}	8.7×10^{-3}	7×10^{-3}
^{101}Sn	-	1	$\sim 2 \times 10^{-4}$	9.3×10^{-3}	$\sim 2 \times 10^{-3}$

Table 1. Compilation of beta-delayed proton data for the precursors ^{105}Sn , ^{103}Sn and ^{101}Sn . The product between on-line overall efficiency η and beta-delayed proton branching ratio P_p is obtained by comparing measured proton activities with primary production rates, the latter being determined by target thickness, ^{58}Ni -beam intensity and calculated cross sections. Using the calculated P_p values one obtains the overall efficiencies given in the last column.

Figure captions

Fig. 1. Excitation functions of fusion-evaporation cross-sections calculated for a 4 mg/cm² thick ^{54}Fe target and a 3.5 mg/cm² thick ^{50}Cr target using the HIVAP code /4/.

Fig. 2. Energy spectrum of beta-delayed protons from the precursor ^{105}Sn , produced in $^{58}\text{Ni} + ^{54}\text{Fe}$ and $^{58}\text{Ni} + ^{50}\text{Cr}$ reactions and measured by an in-beam telescope detector with the mass-105 beam chopped into 50-s collection and 50-s decay intervals. The grow-in decay pattern shown as inset contains experimental data (open points) and results from a least squares fit (solid curve) yielding the indicated half-life. The arrow marks the known end-point energy.

Fig. 3. Energy spectrum of beta-delayed protons from the precursor ^{103}Sn , produced in $^{58}\text{Ni} + ^{50}\text{Cr}$ reactions and measured by an in-beam telescope detector. The decay pattern shown as inset contains experimental data (open points) from a telescope measurement in the counting position of a tape transport system operated with a collection time of 10 s, and includes also results from a least-squares fit (solid curve) yielding the indicated half-life.

Fig. 1

Fig. 2

Fig. 3