Spectroscopy Of N~Z Nuclei: ^{100}Sn And Neighbours

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^{100}Sn is a unique case in the nuclear landscape, being doubly magic and the heaviest particle-stable N=Z nucleus. It is situated close to the proton drip line and thus the path of the rp-process runs close by. The beta-decay of ^{100}Sn is supposed to populate with a large Q-value essentially a single 1^+ state formed by a proton hole in the $g_{9/2}$ and a neutron particle in the $g_{7/2}$ shell. Thus it appears to be the best case to study the Gamow-Teller strength in nuclei. It has been produced [1,2] and studied [1,3,4] already in earlier experiments never identifying more than 14 events. With the improved intensities from the SIS at GSI an experiment with good statistics became feasible.

We have produced ^{100}Sn and nuclei in its neighbourhood by fragmentation of a 1 A·GeV beam of ^{124}Xe on a 4g/cm^2 Be target. The average intensity on target was more than 10^9 ions/s. Redundant measurements of energy loss, magnetic rigidity, and flight time in the second half of the fragment separator (FRS) allowed for a unique identification of the fragments as shown in Fig. 1 for the 15 days of data taking in a ^{100}Sn setting of the FRS. In addition to 259 nuclei of ^{100}Sn we identified for the first time the nuclides ^{93}Ag, ^{95}Cd, ^{97}In and most probably ^{99}Sn. Although we see some events at the location of ^{103}Sb, its half life must be at least a factor of 4 shorter than the flight time through the FRS of 200 ns, in contrast to the literature [5].

The fragments were stopped in a stack of Si detectors. For the correlation of implantation position and time with subsequent decays we used three large area position sensitive Si strip detectors (DSSD'S) with a total of 7200 pixels. Ten 1mm thick Si detectors in front and ten behind this implantation zone served as calorimeters to measure the β-spectrum and to determine its endpoint.

The implantation detector was surrounded by the 105 Ge detectors of the RISING array to observe isomeric decays as well as the γ-deexcitation following β-decays. A number of isomeric states was observed. As an example Fig. 2 shows a delayed γ-spectrum for ^{102}Sn, where we found a new isomeric γ-ray that we attribute to the 6^+-4^+ transition because it is coincident to the other two lines and shows a half-life consistent with that of the other two of 367(11)ns.

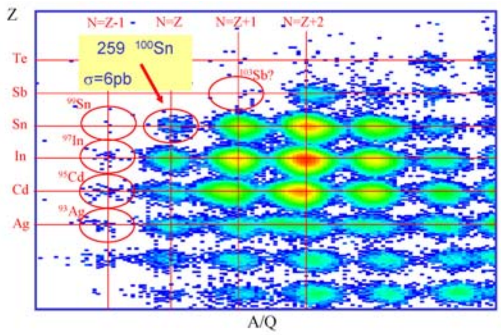

FIGURE 1. Nuclides identified in the FRS during the 15 days irradiation in the setting for ^{100}Sn.

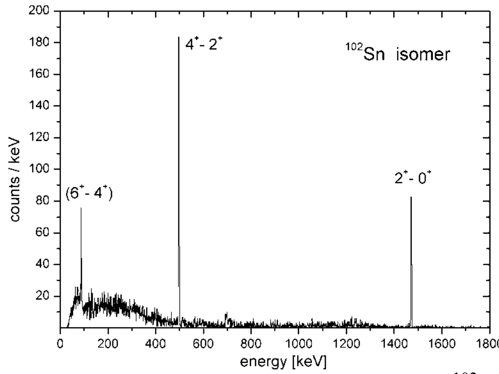

FIGURE 2. Delayed γ-spectrum for ^{102}Sn events. The low energy transition was hitherto unknown and could be interpreted as the 6^+- 4^+ transition.

The β-decay of the implanted nuclei could be measured by observing an energy deposition in the same or in a neighbouring pixel of the DSSD's after the implantation. The sum of the energy depositions in an uninterrupted track in the Si-detectors gave the β-energy. The time correlation then yielded the decay curve. In Table 1 we list the preliminary results for the half-lives of extremely neutron deficient nuclei in the region of ^{100}Sn. In some cases the nuclei were not implanted and half-life limits are determined from their identification after the flight time of 200ns - or their much too low rate. Our results are considerably more precise than the literature values from GSI [3], MSU [4] and GANIL [6], if available. For the N=Z-1 nuclei even the candidate for prompt proton emission ^{97}In decays with a half-life compatible with the expectation for a pure Fermi- plus Gamow-Teller β-decay between mirror nuclei. Proton emission is certainly not the predominant decay mode.

We could for the first time measure a γ-spectrum following the β-decay of ^{100}Sn with five discrete lines. This spectrum supports the theoretical prediction that the β-decay of ^{100}Sn predominantly populates a single 1^+ state in ^{100}In. With this assumption we could fit the observed β-spectrum and extract a preliminary value for the endpoint energy of 3.29(20)MeV. With this endpoint and the half-life we calculate a value log(ft)=2.62(+0.13/-0.18). This is indeed the smallest value among all known β-decays.

For the Gamow-Teller (GT) strength we thus deduce a preliminary value of 9.1(+4.8/-2.3). This value has to be compared with the value 17.78 from the extreme single particle model, assuming that in ^{100}Sn the $g_{9/2}$ shell for the protons is completely filled and the spin-orbit partner $g_{7/2}$ for the neutrons is completely empty. Thus a 'superallowed' GT transition is possible to the $(\pi g_{9/2}^{-1} \otimes \nu g_{7/2})1^+$ state in ^{100}In. The reduction of the experimental value by about a factor of two reflects already the known quenching of the GT strength due to the short range correlations and leaves little room for reduction due to the truncation of the shell model space and long range correlations. It therefore appears that the structure of the ^{100}Sn ground state and the ^{100}In 1^+ state is extraordinarily well described by the simple shell model approach.

TABLE 1. Preliminary half-life values compared with values from the literature.

T_z=(N-Z)/2	Nuclide	$T_{1/2}$	Literature
-1/2	^{93}Ag	>200*ns*	-
-1/2	^{95}Cd	73(+53/-28)*ms*	-
-1/2	^{97}In	26(+47/-10)*ms*	-
-1/2	^{99}Sn	>200*ns*	-
0	^{96}Cd	0.99(13)*s*	1.03(+0.24/-0.21)*s*[4]
0	^{98}In	32(6)*ms*	32(+32/-11)*ms*[3] 47(13)*ms*[4]
0	^{98}In^m	0.86(21)*s*	1.2(+1.2/-0.4)*s*[3] 0.66(40)*s*[4]
0	^{100}Sn	1.16(20)*s*	0.94(+0.54/-0.27)*s*[3] 0.55(+0.70/-0.31)*s*[4]
1/2	^{101}Sn	2.10(10)*s*	1.7(3)*s* [5]
1/2	^{103}Sb	<50*ns*	>1500*ns* [6]

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