IDENTIFICATION OF EXCITED STATES IN THE $N=Z$ NUCLEUS ^{82}Nb*

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Information on the first excited states in the $N = Z = 41$ nucleus ^{82}Nb sheds light on the competition of isospin $T = 0$ and $T = 1$ states in the $A \sim 80$ region. The measurement was performed at the GSI laboratory using fragmentation of a ^{107}Ag primary beam at 750 MeV/u on a 4 g/cm^2 ^{9}Be target. The fragments were separated and identified unambiguously in the FRagment Separator. Three excited states were observed and the half-life estimate for the isomeric state was extracted. A tentative spin assignment based on the isobaric analogue states systematics in the $T_z = 1$ nucleus ^{82}Zr, and transition probabilities indicate $T = 1$ character of the first two excited states, and $T = 0$ for the isomeric state.

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1. Introduction

The low lying excited states in $N = Z$ nuclei at $A \sim 80$ have attracted many recent experimental studies. Most of them aim in the investigation of the competition between isospin $T = 0$ and $T = 1$ configuration expected in odd–odd $N = Z$ isotopes from $A = 76$ to $A = 96$ (see *e.g.* [1] for a recent review). Investigations of $^{62}_{31}$Ga [2], $^{66}_{33}$As [3] and $^{74}_{37}$Rb [4] have identified the ground state configuration with $I^\pi = 0^+$, $T = 1$ is crossed at low excitation energy by a higher spin, $T = 0$ configuration. The small density of the Nilsson single-particle levels in this region of nuclei leads to an abrupt change in the deformation by adding a few nucleons, or with the excitation energy as observed in *e.g.* ^{66}As [3], ^{70}Br [5], ^{78}Sr [6] and ^{82}Zr [6, 7]. Therefore, studies of excited states in heavier $N = Z$ isotopes will shed light on the isospin inversion and the shape evolution toward the doubly magic ^{100}Sn.

2. Experimental details, data analysis and results

The experiment performed at Gesellschaft für Schwerionenforschung (GSI) was part of the Stopped Beam Campaign using the Rare ISotope INvestigation at GSI (RISING) setup [8]. A primary beam of ^{107}Ag at 750 AMeV impinged on a 4007 mg/cm^2 ^{9}Be target. The projectile fragments were separated using the GSI FRagment Separator (FRS) [9] and identified unambiguously in terms of A and Z [10]. The $B\rho - \Delta E - B\rho$ method, used for the particle separation and identification, employed a variable wedge degrader in the middle focal place of the FRS.

At the final focal plane the ions passed through a second variable thickness degrader which slowed them down appropriately for further implantation in a perspex layer of 7 mm thickness.

γ rays were detected by the RISING Ge array consisting of 15 Euroball cluster detectors [11] placed around the stopper. Only delayed γ rays emitted after stopping of the ions were measured. The γ rays time and energy signals were processed by XIA DGF4 [12] digital electronics (25 ns/ch). Additional analog electronic timing branches were used for short ($\leq 0.8\mu$s) and long ($\leq 100\mu$s) isomeric decay correlation times. Further experimental details can be found in Ref. [8].

The identification of ^{82}Nb ions was achieved on two-dimensional spectra analysis of atomic number Z versus A/q ratio. Complementary information was obtained from the position and energy loss of the fragments in the second focal plane of the FRS. For the selected isotope of interest, the delayed γ radiation from the de-excitation of an isomeric state was correlated in matrices of γ-ray energy versus time. The analysis was performed with the CRACOW software [13]. A time window of 25-1800 ns and 12-350 ns with respect to the ion implantation was applied to the DGF4 and short range TDCs, respectively. Three delayed transitions at energies of 123, 418 and 638 keV were associated to the isomer decay in ^{82}Nb. The effective energy threshold of the DGF4 electronic branch was lower (Fig. 1).

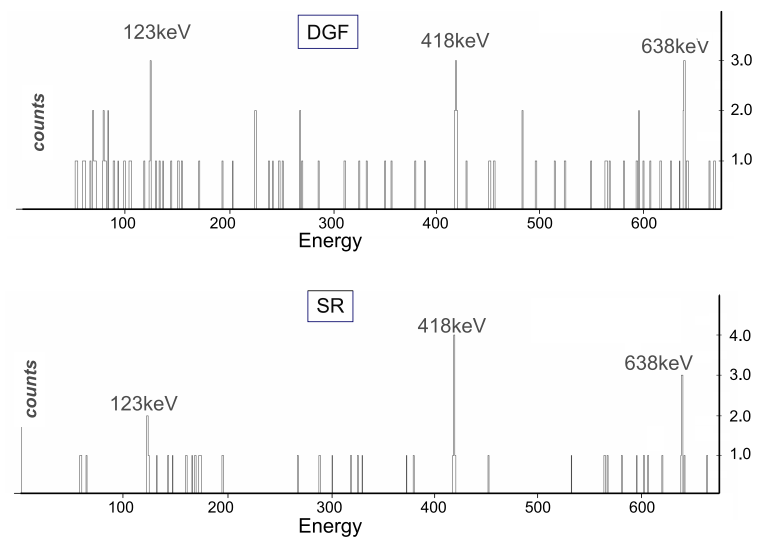

Fig. 1. Gamma ray energy spectrum of ^{82}Nb correlated with the DGF4 (DGF, upper panel) and short range (SR, lower panel) time branches.

The preliminary value of the isomeric half-life in ^{82}Nb was extracted by a fit of a single exponent to the summed time distributions of the 418 and 638 keV γ transitions away from the prompt response. The fit yielding values of 80(50) ns and 75(40) ns for the DGF4 and short range time branches, respectively, used the Maximum Likelihood method for the error bar treatment (Fig. 2).

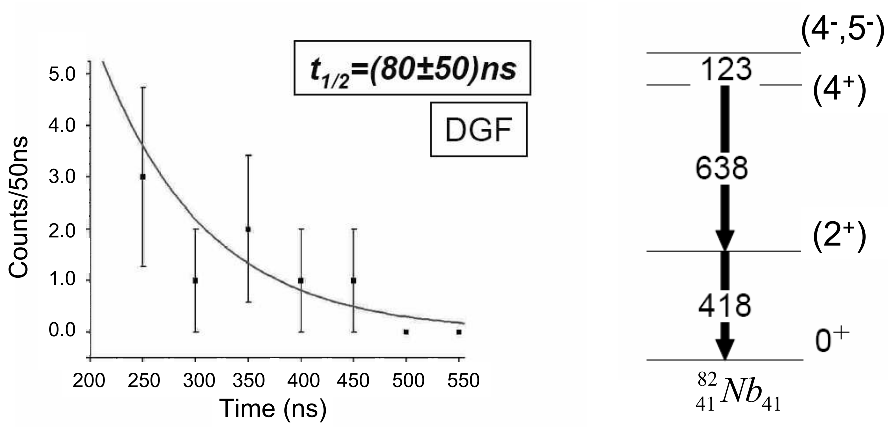

Fig. 2. Left: Isomeric decay curve fit for the DGF4 time branch. Right: Level scheme of ^{82}Nb deduced from this work.

3. Discussion

The ground state spin of ^{82}Nb was deduced *a priori* from the observation of super-allowed Fermi decay and assigned to be $I^{\pi} = 0^{+}$ and $T = 1$ [14]. The existence of short-lived isomeric state in this region of the chart of nuclei was indicated in Ref. [15]. As the ordering of transitions in the level scheme could not be deduced from the present experiment, the systematics was used for this purpose. The average $2^{+} \rightarrow 0^{+}$ and $4^{+} \rightarrow 2^{+}$ transition energy differences between $N = Z$ isotopes and their isobaric $T_z = 1$ analogue states amount to 20 keV and 44 keV, respectively, (^{86}Tc [16], ^{86}Mo [17]), (^{74}Rb [4], ^{74}Kr [6]), (^{70}Br [5], ^{70}Se [18]). Based on the comparison to the known transitions in ^{82}Zr the 418 keV and 638 keV were assigned to the $(2^{+}) \rightarrow 0^{+}$ decay and $(4^{+}) \rightarrow (2^{+})$ decay respectively. The spin of the isomeric state was tentatively deduced from the transition probability analysis to $I^{\pi} = (4^{-}, 5^{-})$. The low statistics did not allow for an unambiguous determination of the conversion coefficient for the 123 keV transition. This assignment implies an isospin change between the isomeric state and the (4^{+}) state. An E1 is the most likely assignment from both lifetime and intensity considerations, but at this stage of the analysis an M1 or mixed M1/E2 can not be ruled out completely for the 123 keV transition. Details of the interpretation will be given in a forthcoming paper.

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