

EXPERIMENTAL STUDY OF NEUTRON-RICH NUCLEI ^{89}Rb AND ^{91}Rb *

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(Received December 15, 2008)

Neutron-rich $^{89,91}\text{Rb}$ nuclei populated as fission products in heavy-ion reactions have been studied with the Gammasphere array. The previously known level schemes have been extended to higher excitation energies and spins. Spin and parity assignments were based on angular correlation analyses. A value of $T_{1/2} = 8(2)$ ns was extracted for the isomeric $g_{9/2}$ state in ^{89}Rb .

PACS numbers: 23.20.Lv, 25.70.Jj, 27.50.+e, 27.60.+j

1. Introduction

Neutron-rich nuclei with masses $A \approx 100$ exhibit a shape transition from spherical to strongly prolate deformed ground states. Sr and Zr isotopes with neutron number between $N = 50$ and $N = 60$ have been extensively studied via different experiments. Evidence of structural changes in these nuclei has been reported [1,2]. Some experimental information is also available on the medium and high-spin states of the Kr isotopes [3]. Much less is known about the structure of odd- Z nuclei in this region, *e.g.* Y and Rb isotopes. We used the data obtained in a series of experiments performed recently at the Argonne National Laboratory to investigate high spin states in the ^{89}Rb and ^{91}Rb isotopes.

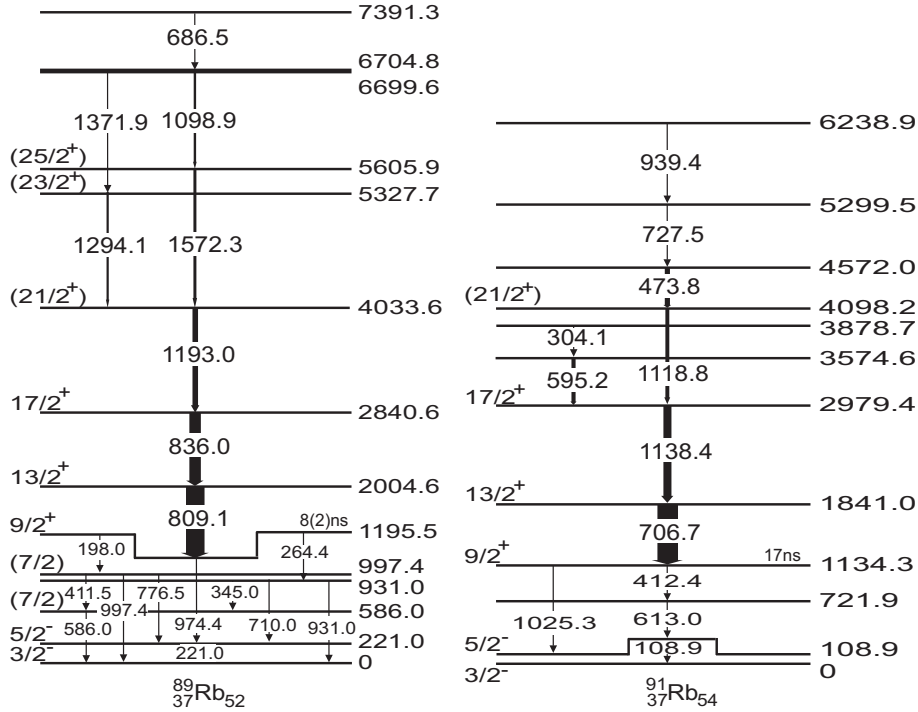
* Presented at the Zakopane Conference on Nuclear Physics, September 1–7, 2008, Zakopane, Poland.

2. Experiments

The nuclei $^{89,91}\text{Rb}$ were produced as fragments of the target-like products in three experiments which were carried out at the Argonne National Laboratory using beams from the Argonne Tandem-Linac Accelerator System (ATLAS). For the $^{48}\text{Ca} + ^{208}\text{Pb}$, $^{48}\text{Ca} + ^{238}\text{U}$ and $^{64}\text{Ni} + ^{238}\text{U}$ colliding systems the beam energies of 305, 330 and 430 MeV were selected, respectively. These correspond to values approx. 20–25% above the Coulomb barriers. In all experiments thick, 50 mg/cm² targets were used. High statistics gamma-ray coincidence data were collected with the Gammasphere array which consisted of 100 Compton-suppressed Ge detectors. The collected energy and timing information served to sort the data into appropriate cubes, as triple gamma coincidences were required to provide satisfactory selectivity. Coincidence events were also analysed with respect to the angle between the detectors and multipolarities were extracted following a gamma-gamma angular correlation analysis.

3. Results

The ^{89}Rb nucleus was previously investigated using β^- decay and the (α, p) reaction in which low-spin states were populated [4]. Recently, the higher lying yrast structure above the $9/2^+$ state was established with multi-nucleon transfer reactions [5]. The present quality of the tripple-gamma coincidence data allowed us to add 5 new transitions above the known ones. In a double-gate set on the previously known 221 and 974 keV γ rays deexciting the 1195 keV level, three strong γ lines have been observed identical with those already observed in a PRISMA-CLARA experiment [5]. In triple γ -coincidence spectra obtained by setting double gates on those three γ rays, five new transitions were observed and subsequently placed in the level scheme. The coincidence analyses performed with data from the three experiments provided essentially identical results. The ^{89}Rb level scheme deduced from the present work is shown in Fig. 1 (left). The resulting angular correlation coefficients for the 974–221 keV sequence ($a_2 = -0.16(4)$) support a quadrupole-dipole character, which is consistent with the $9/2^+$ assignment of the 1195 keV level. Similarly, the analysis of the 809–836–1192 keV cascade indicates quadrupole-quadrupole character of all transitions involved ($a_2 = 0.15(8)$ and $a_2 = 0.17(5)$ respectively). Thus, assignments of $13/2^+$, $17/2^+$ and $21/2^+$ are adopted for the states at 2005, 2841 and 4034 keV, consistent with previous suggestions [5]. The levels at 5328 and 5606 keV are tentatively assigned $23/2^+$ and $25/2^+$, as predicted in shell model calculations discussed by the authors of Ref. [5]. The established level scheme allowed to analyse the timing parameter in delayed coincidences between gamma transitions above and below the $9/2^+$ state. This enabled the determination of the half-life of $T_{1/2} = 8(2)$ ns for the $9/2^+$ isomeric state. This level predominantly decays by an M2 transition.

Fig. 1. Level schemes of ^{89}Rb and ^{91}Rb .

The ^{91}Rb nucleus has been studied previously in β decay, and therefore, only low-spin states were known prior to our study including the 17 ns $9/2^+$ isomeric state [6]. In the present work the assignment of γ lines to ^{91}Rb is based on coincidence spectra obtained with double gates set on transitions below this $9/2^+$ isomer at 1134 keV and confirmed by examination of delayed coincidences across the isomer. This analysis allowed to identify eight new γ transitions. Their relative intensities and coincidence relations were used to place them in the level scheme of Fig. 1 (right). A γ - γ angular correlation analysis settles the quadrupole character of the 707–1138–1119 keV cascade ($a_2 = 0.18(3)$ and $a_2 = 0.09(6)$, correspondingly). Consequently, spins and parities $13/2^+$, $17/2^+$, $21/2^+$ are adopted for the states at 1841, 2979, 4098 keV, respectively. The statistics was too poor to obtain any significant anisotropy results for other transitions.

Fig. 2 shows the evolution of the yrast states observed in odd- A Rb isotopes. This systematics shows that the yrast transitions identified in this work follow smoothly the trend observed in lighter nuclei. The evolution also supports the assignment of $9/2^+$ to the 1134 keV state rather than the $7/2^+$ proposed in Ref. [6].

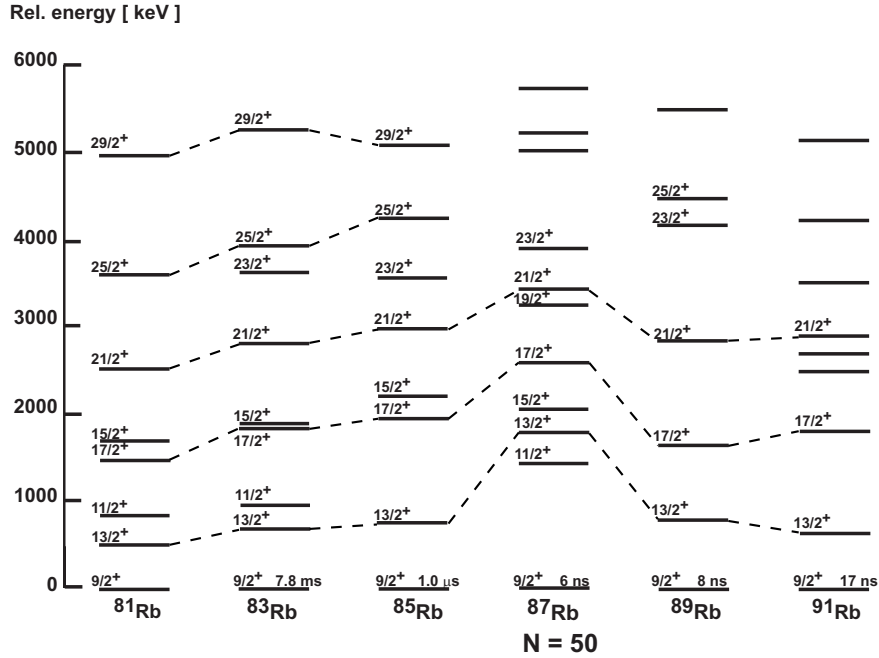


Fig. 2. Systematics of yrast states observed in odd- A Rb isotopes.

4. Conclusions

The $^{89,91}\text{Rb}$ isotopes have been produced in three different reactions. The already known high-spin level scheme of ^{89}Rb has been improved and the half-life of the $9/2^+$ isomer was determined. High-spin states in ^{91}Rb have been identified for the first time. Spin-parity assignments for the strongest transitions were obtained from a γ - γ correlation analysis. These new results extend the experimental data systematics of Rb isotopes and will be helpful to further develop the shell model for nuclei with $N > 50$ and $Z < 38$.

This work is supported by the Polish Ministry of Science, Grants No 1P03B05929 and NN202103333, and by the U.S. Dept. of Energy, Office of Nuclear Physics under contract DE-AC02-06CH11357.

REFERENCES

- [1] E.A. Stefanowa *et al.*, *Phys. Rev.* **C65**, 034323 (2002).
- [2] D. Pantelica *et al.*, *Phys. Rev.* **C72**, 024304 (2005).
- [3] T. Rząca-Urban *et al.*, *Eur. Phys. J.* **A9**, 165 (2000).
- [4] B. Singh, *Nucl. Data Sheets*, **85**, 1 (1998).
- [5] D. Bucurescu *et al.*, *Phys. Rev.* **C76**, 064301 (2007).
- [6] K. Sistemich *et al.*, *Z. Phys.* **A325**, 139 (1986).