ALPHA-GAMMA DECAY STUDIES OF ^{261}Sg*

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The isotope ^{261}Sg was produced in nuclear reaction ^{208}Pb(^{54}Cr,n)^{261}Sg at velocity filter SHIP in GSI Darmstadt. Its decay products ^{257}Rf and ^{253}No were studied by means of α, α–γ and/or α–X-ray spectroscopy. Improved spectroscopic data for these isotopes is presented as well as new information concerning J^{π} values of Nilsson single neutron orbitals in heaviest members of $N = 151$, 153 and 155 isotonic chains.

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1. Introduction

The research of low lying single-particle orbitals in odd-A heavy nuclei provides a unique probe to nuclear structure and is a valuable source of information needed for testing reliability and predicting power of theoretical models based on macroscopic–microscopic approach [1, 2]. Nuclear structure investigations of the isotopes in transfermium region have been in past decade extended to include methods of α–γ and/or α-conversion electron (CE) spectroscopy [3]. These methods allow more detailed studies of isotopes which are known but for which only rough information was obtained until now. An example is recently studied odd-A nucleus ^{261}Sg.

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The aim of present study is to extend the systematics of single-neutron states in $N = 151$, 153 and 155 isotones by experimental spin-parity assignment and also gain information of potential isomeric states using aforementioned spectroscopy methods.

2. Experimental procedure

The isotope ^{261}Sg was produced in two separate experiments at the velocity filter SHIP in GSI, Darmstadt. The used beam of $^{54}Cr^{7+}$ ions had average intensity of 900 and 650 pnA, respectively, and was focused on ^{208}Pb target. The targets with average thickness of 430 μg/cm^2 were evaporated on 40 μg/cm^2 carbon backing and covered with 10 μg/cm^2 carbon foil. They were mounted on the rotating wheel synchronized to the pulse's macrostructure[1]. Nine beam energies ranging from 4.70 to 5.17 AMeV were chosen to measure the excitation function in first experiment. In the second one the energy 4.77 AMeV of the maximum of excitation function was used. In-flight separation of evaporation residues was done by SHIP with transmission efficiency of $\varepsilon \sim 40\%$. The STOP detector calibration in the first experiment was done using long living activities of ^{206,208,210}Po and one fast decaying transfer product ^{211}Po, while second experiment used a test reaction ^{164}Dy(^{54}Cr,4n)^{214}Th for calibration purposes. Gamma detectors were calibrated using the γ-sources of ^{152}Eu and ^{133}Ba. More experimental details can be found in [4].

3. Results

Decay spectroscopy methods were used to analyze the acquired data. Namely, α-decay spectroscopy combined with the method of generic linking of decay sequences to initial decay of evaporation residue (ER) by ER-α and α–α correlation analysis. In order to extract more detail information about the nuclear structure of these isotopes, also the methods of prompt and/or delayed α–γ coincidences were used.

This work attempted to construct the decay scheme of the isotope ^{261}Sg. New α-lines at 9345(20) and 9620(20) keV were measured with collective half-life of $T_{1/2} = 184 \pm 5$ ms for this isotope. In prompt coincidence with α-decays of ^{261}Sg the γ-energy of 107 keV was measured de-exciting the level in daughter nucleus ^{257}Rf with probable M1 multipolarity. The K X-rays were measured for the first time for the element with $Z = 104$ and the ratio $I_{K_{\alpha_1}}/I_{K_{\alpha_2}} = 2.2 \pm 1.2$ was obtained. The improved value on the total cross-section of $\sigma = 2.2 \pm 0.2$ nb was calculated for ^{208}Pb(^{54}Cr,n)^{261}Sg reaction with the maximum of excitation function at $E^* = 16.9 \pm 0.2$ MeV using metallic targets in first experiment. This value was later confirmed by measuring $\sigma = 2.02 \pm 0.06$ nb using the compound PbS targets.

[1] In average, 5 ms beam was followed by 15 ms pause.

A complex α-spectrum for ^{257}Rf was measured with the admixture of its EC-product ^{257}Lr. The α-decays from $11/2^-$ isomer in ^{257}Rf were not observed in its indirect production via the decay of ^{261}Sg. In its direct production via ^{208}Pb(^{50}Ti,n)^{257}Rf reaction, α-spectrum from the ground-state (g.s.) decay is partly overlaid by α-decays from this isomer [5]. This work allowed to extract the g.s. α-transition resulting in Q_α-value of 9092 keV for ^{257}Rf.

From delayed α-X-ray coincidences the half-life of the isomer $5/2^+[622]$ in ^{253}No was calculated with $T_{1/2} = 24.6^{+5.0}_{-3.6}$ μs in perfect agreement with the value measured in direct production of ^{253}No at SHIP [6]. Moreover, the analysis unambiguously identified the γ-transition of $E_\gamma = 167$ keV depopulating the isomer by M2 transition to the ground-state and it was also confirmed in direct production of ^{253}No with $T_{1/2} = 21.6 \pm 2.2$ μs. The level in ^{253}No populated by 8495 keV α-transition was observed to decay by 283 keV γ-transition to $5/2^+[622]$ isomer and tentatively assigned as E2. Proposed nuclear decay schemes for the isotopes ^{261}Sg and ^{257}Rf are presented in Fig. 1.

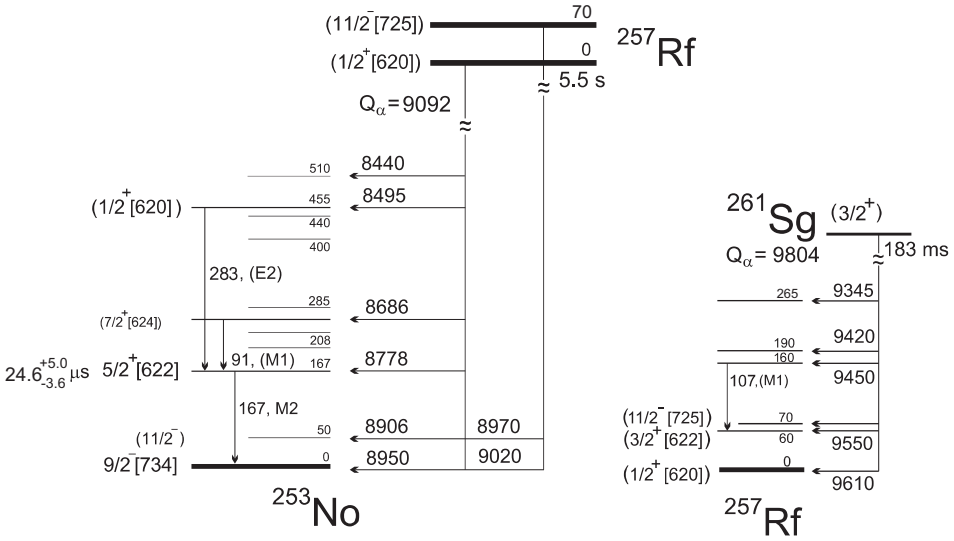

Fig. 1. The proposed decay schemes for ^{261}Sg and ^{257}Rf.

4. Summary and perspectives

Presented spectroscopic information on α and γ transitions derived in these experiments enabled improvement of level schemes of ^{257}Rf and ^{253}No. Even though the quality of the data is not sufficient for unambiguous identification of spins and parities of involved levels some conclusions could be made. For the mother nucleus ^{261}Sg we assigned the g.s. as $J^\pi = 3/2^+$ in line with the recent results on ^{257}No [7] and this work. The change of the g.s. J^π from $7/2^+$ to $3/2^+$ for $N = 155$ isotones is not in line with the theoretical predictions based on microscopic-macroscopic approach [1,2]. On the other hand the experimental nuclear levels in $N = 153$ isotones including our tentative interpretation of the data for ^{257}Rf with $1/2^+$ g.s. and $3/2^+$, $11/2^-$ first excited single neutron levels, fit nicely to these calculations. The identification of 167 keV γ-transition as M2 in ^{253}No depopulating the isomeric $5/2^+[622]$ single neutron orbital to the g.s. and tentative assignment of E2 to 283 keV γ-transition observed to populate $5/2^+[622]$ isomer from above, confirmed the continuation of the experimental systematics of low lying nuclear levels in $N = 151$ isotones.

It needs to be stressed that more measurements are necessary in order to clarify these assignments, especially the g.s. of $3/2^+$ in ^{261}Sg. Detail investigation of the nucleus ^{259}Rf would contribute to the research of $N = 155$ isotones, providing missing link between presented data for ^{261}Sg and recent results for ^{257}No [7]. Another challenge lies in improvement of theoretical models that so far fail to successfully reproduce the experimental data for the range of isotones around $N = 153$. More detail discussion on nuclear systematics in these isotones will be presented in Ref. [4].

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