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NEAR-YRAST EXCITATIONS IN NUCLEUS ^{83}As: TRACING THE DEFORMATION IN THE ^{78}Ni REGION*

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Medium-spin, yrast excitations in nucleus ^{83}As have been studied in neutron-induced fission of ^{235}U. The experiment took place at the Institut Laue-Langevin in Grenoble where gamma rays were registered using the EXILL detector array. Recently, we proposed new tentative $(9/2^{+})$ spin assignment for 2777 keV level in ^{83}As, which is now discussed in the context of deformation showing up in ^{78}Ni region.

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1. Introduction

Studying shell effects in nuclei far from stability is one of the most intriguing problems of contemporary nuclear structure examinations. Over the last few years, considerable experimental and theoretical effort has been focused on exploring nuclei in the region of ^{78}Ni (see Ref. [1, 2] and references therein). On the one hand, this nucleus, having $N = 50$ and $Z = 28$, is expected to be a reliable, doubly magic core for shell-model calculations. However, due to the unusually high neutron-to-proton ratio, the $Z = 28$ shell closure resulting from the spin–orbit splitting might be weakened as suggested in Ref. [3]. Hence, the quadrupole excitations of the Ni core might be significant in the structure of nuclei in this region. The systematic investigations along isotonic chains provide valuable information on the behaviour of proton single and multiparticle excitations as well as collective phenomena, when approaching $Z = 28$. To broaden the knowledge on $N = 50$ isotones, we investigated the structure of ^{83}As. The results were presented recently in Ref. [1] which is summarized and complemented by this work with new systematics and discussion on deformation.

2. Experiment and previous spectroscopic results

The nucleus ^{83}As was populated in the neutron induced fission of ^{235}U. Prompt gamma rays were detected using the EXILL array consisting of 16 HPGe detectors arranged in a polyhedron frame [4, 5], placed at the PF1B cold-neutron beam of the Institut Laue-Langevin in Grenoble. The neutron beam was collimated to 12 mm in diameter at a capture flux of about $10^8/(\mathrm{s\ cm}^2)$. The fissile material was ≈ 0.6 mg of ^{235}U. Events were recorded in triggerless mode using a fast, digital acquisition system with a 100 MHz clock [6], which enabled detailed analysis of double and triple gamma coincidences within different time windows. During 21 days, 15 terabytes of data were collected.

In Ref. [1], the known level scheme of ^{83}As was verified and updated. Energies and intensities of gamma transitions were determined with a greater precision than in previous works [7, 8] thanks to higher statistics. One new cross-over transition of 1316 keV was added to the level scheme, but the 316 keV line reported in [9] was not confirmed. The level scheme is presented in Fig. 1. Illustrative gamma spectra and relevant discussion can be found in Ref. [1].

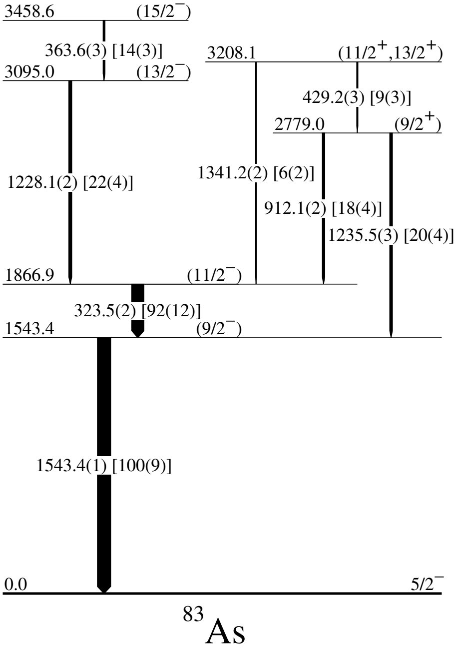

Fig. 1. Level scheme of ^{83}As after Ref. [1]. Energies are presented in keV and intensities (in brackets) in relative units. Both values are given with uncertainties.

3. Tentative $(9/2^+)$ spin assignment

An important point of our previous work [1] was the tentative $(9/2^+)$ spin assignment to the level at 2777 keV, which was motivated by a handful of premises *i.e.* the calculations performed in Refs. [7, 8, 10], the non-observation of 316 keV transition claimed in Ref. [9] and the systematics along isotopic chains (see Fig. 4 in Ref. [1]). For completeness, in Fig. 2, the energy difference between $9/2^+_1$ and $5/2^-_1$ levels in isotones having $N = 42$–50 is presented for odd-Z Cu to Rb elements. The point added after our spin assignment (at the top of the plot) matches well the general trend.

The 2777 keV level is proposed to result from proton excitation to the $\pi g_{9/2}$ orbital. This information turned out to be helpful in optimizing shell-model parameters for $N = 50$ isotones by Sieja [1] — the single particle energy of $\pi g_{9/2}$ in ^{78}Ni core extracted from this solution yields about 5.7 MeV. The modified parametrization was successfully applied to calculate structure of ^{88}Br [12], ^{90}Rb [13] and ^{86}Se [14].

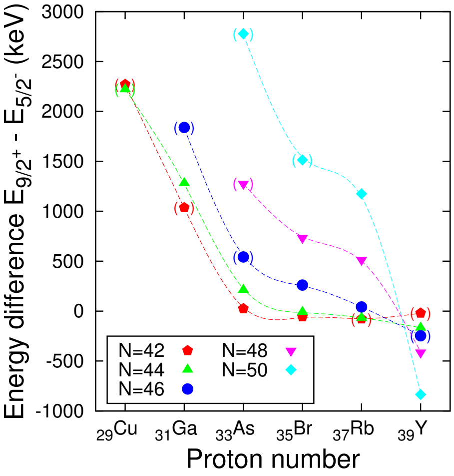

Fig. 2. Systematics of $9/2^+$ levels relative to $5/2^-$ levels based on data from [11]. The difference of their energies is presented for various isotonic chains. Dashed lines are drawn to guide the eye.

4. Interpretation within the Nilsson model

As predicted by the shell model, the difference of $\pi g_{9/2}$ and $\pi f_{5/2}$ single particle energies in the ^{78}Ni core is about 5.7 MeV. Therefore, in the $N = 50$ isotones, the first $9/2^+$ level, which results from the $\pi f_{5/2} \to \pi g_{9/2}$ excitation, should have also considerably high excitation energy. However, in the nucleus ^{83}As, which has only 5 valence protons added to ^{78}Ni core, the $9/2^+$ level lies only 2.7 MeV above the $5/2^-$ ground state. The question arises about the mechanism behind the 3 MeV lowering. It seems that even a small deformation may influence the single particle energies and, in turn, nuclear structure in the nucleus. The Nilsson model provides a quantitative picture of splitting of the spherical single particles orbitals, with respect to deformation parameter. Indeed, such an approach matches well the experimental data. With a prolate deformation, the $\pi g_{9/2}$ orbital splits and 1/2[440] Nilsson orbital goes down in energy (see Fig. 3). This orbital and the orbitals coming from $\pi f_{5/2}$ splitting are then populated providing spin and parity $9/2^+$, as illustrated in Fig. 3. The proposed configuration results from breaking one proton pair and promoting two protons to the nearby orbitals. The required energy may be gained by a slight change of deformation between the ground state and the excited state. The first one is limited to the small deformation parameters in order to correctly reproduce its spin and parity $5/2^+$.

The deformation is also predicted in the neighbouring nuclei. Porquet *et al.* [7] report that a theoretical "rotor + quasiparticle" approach, which takes the deformation into account, is successful in reproducing the major properties of the low-energy spectrum of ^{81}As. Moreover, in a recent work by Materna *et al.* [14], the maximum of collectivity for the $N = 52$ isotones is suggested to be reached for $Z = 32, 34$. For ^{83}As with $N = 50$, the deformation might be a result of the weakening of the $Z = 28$ shell closure, enabling therefore quadrupole excitations involving the $\pi f_{7/2}$ orbital.

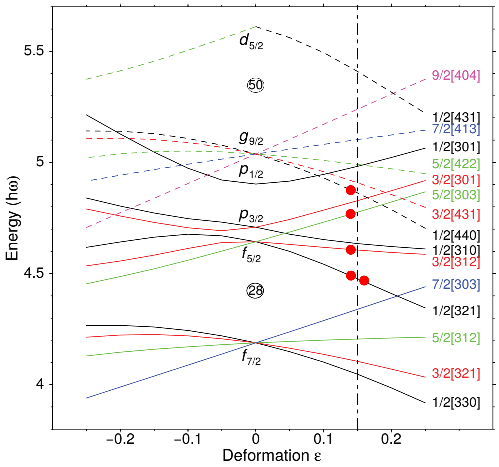

Fig. 3. (After Ref. [7]) Single-particle proton levels of the modified harmonic oscillator as a function of quadrupole deformation, ϵ, calculated for $N \approx 50$ (see Ref. [7] for details). Dots represent the possible level population leading to a $9/2^+$ state.

5. Summary

The tentative $(9/2^+)$ spin assignment for the 2777-keV level in ^{83}As, proposed in our previous work [1], is supported by the systematics of energy differences in isotonic chains. The low energy of the $(9/2^+)$ level may be explained qualitatively by referring to the Nilsson model and the lowering of the 1/2[440] orbital, originating from the $\pi g_{9/2}$ shell, due to prolate deformation occurring in this nucleus.

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