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SHAPE COEXISTENCE IN EVEN–EVEN Mo ISOTOPES STUDIED VIA COULOMB EXCITATION*

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The nuclei ^{96}Mo and ^{100}Mo have been Coulomb excited using various combinations of beams and targets. The investigation of the electromagnetic structure of these isotopes provides an experimental background for a theoretical description of the shape coexistence observed in the previously studied ^{98}Mo isotope.

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1. Introduction

The data obtained using the Coulomb excitation method allow to determine nuclear deformation in both ground and excited states. The nucleus ^{98}Mo is one of the four stable nuclei heavier than calcium having the first excited state of spin and parity 0^+. Shape coexistence in ^{98}Mo manifests in the very different triaxiality of the two first 0^+ states [1, 2]. The properties of the first excited state of ^{98}Mo could not be described by the microscopic model based on generalised modified Bohr Hamiltonian including the dynamic effects of the nucleon pairs correlations [3], although in cases of Ru

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and Pd isotopes predictions of this model were in good agreement with the experimental data [4]. In particular it seems that the role of the proton-neutron pairing (isoscalar component of the pairing forces) with respect to the quadrupole degrees of freedom should be explained [5,6]. The confirmation of these suggestions require further theoretical efforts with the stress on the probably strong dependence of the collective properties of the first excited state of spin zero on the numbers of protons and neutrons in a given isotope. Precise experimental data on neighbouring isotopes are required to explain the possible effect of proton-neutron pairing, as well as to provide the arguments to discuss still not clear problem of the coexistence of the isoscalar and isovector phases in the pairing interaction.

2. Experiments

2.1. Coulomb excitation of ^{96}Mo

Three experiments were performed to study ^{96}Mo: two at Heavy Ion Laboratory in Warsaw with ^{20}Ne and ^{40}Ar beams and a ^{96}Mo target of the thickness 4.9 mg/cm^2 and the third one at Japan Atomic Energy Research Institute (JAERI, Tokai) with a ^{96}Mo beam and a $^{\mathrm{nat}}$Pb target 1.4 mg/cm^2 thick. In every case the emitted γ rays were measured in coincidence with scattered particles. For all experiments beam energies were as close as possible to the "safe" energy according to the Cline's criterion [7] for a given angle, as demonstrated in the Table, therefore the multi-step excitation was strongly favoured. For the experiments performed at Heavy Ion Laboratory a dedicated detection set-up CUDAC [8,9] (Coulex Universal Detector Array Chamber) consisting of 30 PIN-diodes and supported by 3 HPGe detectors was used. PIN-diodes were placed at angles from 130° to 150° and γ-ray detectors at 35°, 113° and 130° with respect to the beam direction. The GEMINI gamma-ray detection set-up at JAERI during the experiment consisted of 16 anti-Compton suppressed germanium detectors. Out of six position-sensitive particle detectors of LUNA set-up [10] only the forward ones (covering angles from 27° to 74° with respect to the beam direction) were used. The molibdenium beam was extracted for the first time from the JAERI tandem accelerator.

TABLE

Energies of beams used in the presented experiments compared to "safe" energies calculated for maximum scattering angles.

Beam	Maximum scattering angle (LAB)	Beam energy	"Safe" energy
^{20}Ne	150°	50 MeV	52 MeV
^{40}Ar	150°	100 MeV	103 MeV
^{96}Mo	74°	424 MeV	460 MeV

2.2. Coulomb excitation of ^{100}Mo

The experiment of Coulomb excitation of ^{100}Mo using the 90-MeV ^{40}Ar beam has been recently performed at Heavy Ion Laboratory. Another experiment with a 50-MeV ^{20}Ne beam is scheduled for autumn 2004. The details can be found in [11].

3. First results and summary

The level scheme of ^{96}Mo showing transitions observed in the ^{96}Mo + $^{\rm nat}$Pb experiment is presented in Fig. 1 and a sample Doppler-corrected spectrum from the same experiment is shown in Fig. 2.

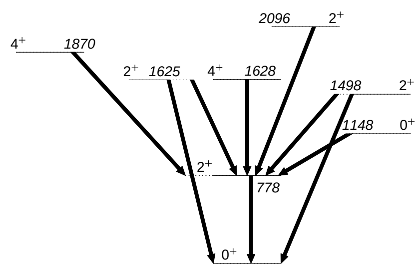

Fig. 1. Low-lying excited states of the ^{96}Mo nucleus. The transitions observed in the ^{96}Mo + $^{\rm nat}$Pb experiment are marked with arrows. All energies are given in keV.

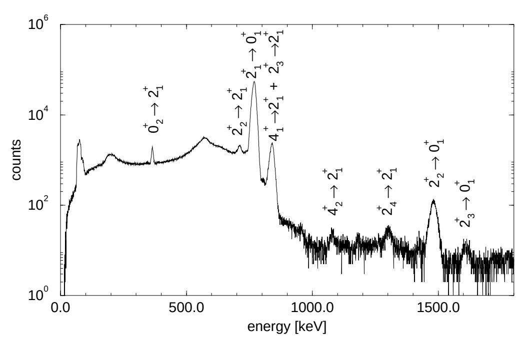

Fig. 2. Gamma-ray spectrum observed in coincidence with scattered ^{96}Mo ions in the ^{96}Mo + $^{\rm nat}$Pb experiment.

Since the difference between the 4_1^+ and 2_3^+ level energies is smaller than 3 keV, in the present experiments it was not possible to resolve the observed doublet $(4_1^+ \rightarrow 2_1^+)$ & $(2_3^+ \rightarrow 2_1^+)$ despite the application of the Doppler-shift correction. Therefore the observation of the $2_3^+ \rightarrow 0_1^+$ transition is of special importance, since the branching ratio $(2_3^+ \to 2_1^+)/(2_3^+ \to 0_1^+)$ is known [12]. This transition was observed only in the ^{96}Mo + $^{\mathrm{nat}}$Pb experiment, since the excitation of the relatively high-lying 2_3^+ state was too weak when using lighter beams.

The obtained data are being presently analysed using the GOSIA code [13]. One expects to obtain the complete set of $E2$ matrix elements connecting the 0^+ and the 2^+ states, including the quadrupole moments for all the observed 2^+ states in the ^{96}Mo nucleus. It should allow to determine the quadrupole deformation parameters for both 0^+ states as it was done in the ^{98}Mo case [1, 2] and to study their dependence on the neutron number.

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