Static and dynamic deformation of the nuclei of europium and samarium isotopes in the transition region

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Isotopic changes in the mean square charge radii and the quadrupole moments of the nuclei of Eu and Sm isotopes have been measured over the mass interval $144 < A \leqslant 155$. The results make it possible to distinguish the static deformation from the dynamic deformation of these nuclei.

The isotopic shifts and the hyperfine splitting of the optical spectra of series of europium and samarium isotopes including nuclei in the transition region, with neutron numbers $N = 82$–90, have been measured on the IRIS mass separator at the Leningrad Institute of Nuclear Physics. The measurement method is a method of collinear laser-ion spectroscopy developed at Marburg University. We have also determined the quadrupole moments of the ground states of the nuclei and the changes in the mean square charge radii with respect to the reference nuclei ^{145}Eu and ^{144}Sm with a filled $N = 82$ neutron shell.[1]

There is considerable interest in distinguishing the static deformation (δ_c) of nuclei, which is a measure of the deviation from the equilibrium shape, from the dynamic deformation (δ_g), which is associated with oscillations of the nuclear surface. The values of δ_c were determined from the measured quadrupole moments with the help of shell-model formulas, while the values of δ_g were found from the changes in the mean square radius, $\Delta^{AA'}\langle r^2\rangle \equiv \langle r^2\rangle_A - \langle r^2\rangle_{A'}$, from the following formula:

$$\Delta^{AA'}\langle r^2\rangle = \frac{3}{5}\rho\,\Delta^{AA'}R_0^2 + \frac{3}{4\pi}R_0^2\,[\,\Delta^{AA'}\delta_c^2 + \Delta^{AA'}\delta_g^2\,]\,, \tag{1}$$

where $R_0 = 1.2A^{1/3}$ fm. The isotopic-anomaly parameter ρ was assumed to be 0.66 for Eu and 0.69 Sm. The nuclei ^{145}Eu and ^{144}Sm, with the neutron number $N = 82$, were assumed to be spherical ($\delta_c = 0$), while their dynamic deformation was specified on the basis of the known value of the reduced probability for the $0^+ \to 2^+$ transition of the nucleus of ^{144}Sm. For the even-even isotopes, the static deformations were calculated from the quadrupole moments of the 2^+ first excited states, measured by a orientation-reversal method in Coulomb-excitation experiments.[2] We used the formulas of the Davydov-Chaban nonadiabatic theory, with the values of the softness parameter μ and the nonaxiality parameter γ determined from the ratio of the energies of the first two 2^+ excited states.

The results (Fig. 1) may be taken as direct confirmation of the existence of small equilibrium deformations of the nuclei of the isotopes ^{147,149,151}Eu with neutron

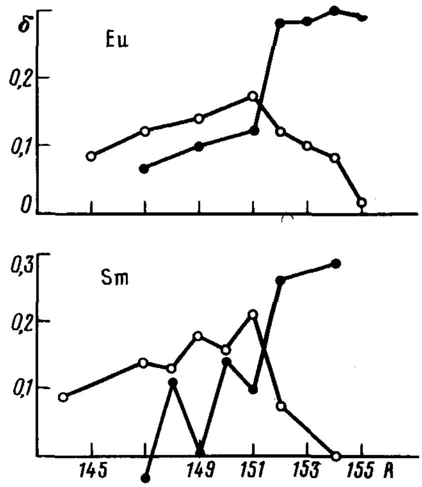

FIG. 1. Static deformation (filled circles) and dynamic deformation (open circles) versus the mass number of the nuclei of Eu and Sm isotopes.

numbers below 90. The slow increase in the static deformation with increasing neutron number at $N < 89$ and also the more rapid increase in the static deformation near $N = 89$–90 agree with the interpretation of Refs. 3, where, in particular, the deformation parameters were estimated by minimizing the sum of the single-particle energies (in accordance with the Mottelson-Nilsson method) without consideration of pairing. The good agreement between the values found for δ_c and the predictions of Ref. 3 evidently means that pairing correlations have little effect on the shape of these nuclei. Recent indications[4] of the magic nature of the isotope ^{146}Ge with respect to both protons and neutrons suggest that the proximity of these nuclei to the "doubly magic" nucleus ^{146}Gd may be responsible for the minor role played by pairing effects.

For the slightly deformed nuclei of the isotopes ^{147,149,151}Eu, the dynamic deformation exceeds the static deformation and increases along with the latter with increasing neutron number (Fig. 1). When the 89th neutron is added, however, and the static deformation increases abruptly, the dynamic deformation decreases, becoming much smaller than the static deformation. A similar situation is observed in the case of the samarium isotopes, with the distinction that the sharp increase in the static deformation and the decrease in the dynamic deformation occur when the 90th neutron is added. A decrease in the static deformation upon the addition of an odd neutron to the even-even isotopes ^{148}Sm and ^{150}Sm is interesting.

We wish to stress that in our analysis of the data we have used approximate formulas based on simple nuclear models. For this reason, the results are to some extent merely qualitative. We, believe, nevertheless, that although a more accurate analysis may lead to slightly different concrete values for the static and dynamic deformations, they will not cause any important deviation from the relative behavior of these deformations shown in Fig. 1.

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