MASS AND QUADRUPOLE MOMENTS CALCULATIONS FOR Cs AND Ba ISOTOPES*

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Using the macroscopic-microscopic model, the masses and quadrupole moments for Cs and Ba isotopes are calculated. It is performed in the six-dimensional deformation space $\{\beta_\lambda\}$, $\lambda = 2, 3, 4, 5, 6, 7$. The quadrupole moments are evaluated in single particle, pairing and macroscopic models. The results are compared with the experimental data.

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1. Introduction

A continuing progress in the precise measurements of nuclear masses [1] imposes increasing demands for the theoretical description of ground state properties [2, 3] as energy and quadrupole moments. In the present work the ground-state potential energy [4] and quadrupole moments for the isotopes of Cs and Ba are analyzed. The energy is calculated in a multi-dimensional deformation space by the macroscopic-microscopic method. The Yukawa-plus-exponential model [5] is used for the macroscopic part of the energy. The Strutinski shell correction [6] and Lipkin–Nogami approach to pairing

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[7], both based on the Woods–Saxon single-particle potential [8], are taken as the microscopic part. The six axially-symmetric deformations $\beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7$, are taken into account. The pairing force strength is parametrized according to [3].

The quadrupole moments for protons are calculated in microscopic and macroscopic approaches [9,10]. The microscopic approach consists of the two steps:

(a) for each proton orbit the single particle quadrupole moment is evaluated,

(b) the moments are summed up to the Fermi level, forming the single particle quadrupole moment of the nucleus ($Q_0^{\rm SP}$), or are added together with the weights equal to the occupation probabilities from the Lipkin-Nogami model, yielding the quadrupole moment accounting for the pairing interactions ($Q_0^{\rm LN}$).

The macroscopic quadrupole moment $Q_0^{\rm M}$ is calculated by integration over uniformly charged nuclear shape (deformation is taken from the mass calculations).

2. Results

In the mass calculations both pairing and macroscopic parameters are adjusted for each isotopic chain separately. The minimization in multidimensional deformation space reveals existence of octupole deformation for the neutron-rich isotopes of Cs (N=85-94) and Ba (N=86-92). The values of β-deformations for even-even Ba isotopes are in agreement with [11], except for N=94. The β_2-values in some cases rapidly change from positive to negative value as a function of N. This indicates the possibility of shape-coexistence in these nuclei (existence of both prolate and oblate shape for a given nucleus). This effect is important in the calculation of quadrupole moments.

The final results of the mass calculations are compared in Fig.1 with another macroscopic-microscopic model predictions [12], where the model parameters were fitted globally for all known nuclei.

The root mean square (RMS) deviations of the theoretical values of nuclear masses from experimental ones are calculated for our points (circles) and those of Ref. [12] (triangles).

Because of locality of our fit and a greater deformation space as compared to [12], we have better overall description of all the masses. For Cs and Ba, in the vicinity of $N = 82$ the discrepancy between theory and experiment is increasing, probably due to the deficiency of pairing correction close to magic numbers. The model description is also worse for the lightest isotope of cesium, which might be due to one-particle instability of this nucleus.

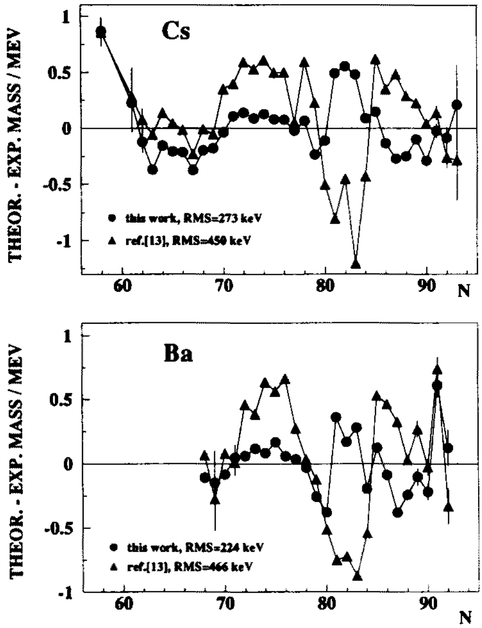

Fig. 1. The difference between theoretical and experimental mass [13] as a function of neutron number. See text for explanations.

In Fig. 2 both theoretical and experimental intrinsic quadrupole moments Q_0 are presented. The experimental ones are extracted [9] from the formula (valid for well deformed nuclei):

$$Q_0 = \frac{(I+1)(2I+3)}{I(2I-1)} Q_s , \qquad (1)$$

where I is the spin, Q_s — spectroscopic quadrupole moment of the nucleus.

It is seen that the $Q_0^{\rm LN}$ moments are close to $Q_0^{\rm SP}$ ones (discrepancy about a few per cent). The macroscopic $Q_0^{\rm M}$ moments are generally lower than the microscopic ones (see [14]). For Ba isotopes the discrepancy between theoretical and experimental values is rather small (except for $N = 87$ where the signs of the theoretical and experimental quadrupole moments are opposite). For Cs isotopes the theory describes well the experimental data only for the nuclei with large deformation β_2, *e.g.* in the vicinity of neutron numbers $N = 90$ and $N = 66$. Around the magic number $N = 82$ experimental moments are close to zero — in agreement with the theory. However, for $N = 69, 71, 73$ the experimental data have larger absolute values and opposite sign compared to the theoretical ones.

This discrepancy could possibly be removed by including the γ-deformation and rotor plus particle coupling in our model. The existence of γ-de-

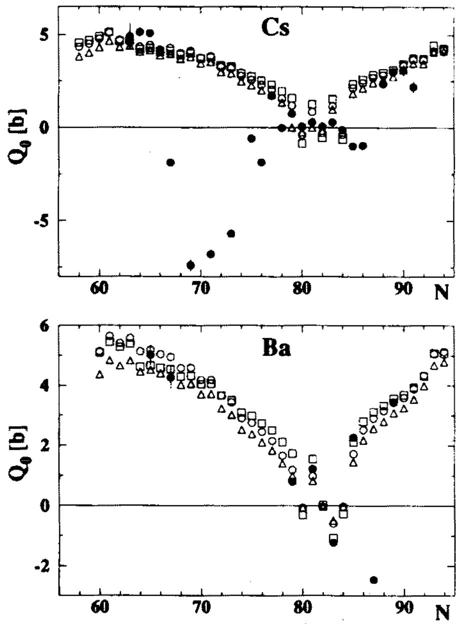

Fig. 2. The experimental [15, 16, 17, 18] and theoretical quadrupole moments for Ba and Cs isotopes. Full circles: experiment. Open symbols: circles — Q_0^{LN}, squares — Q_0^{SP}, triangles — Q_0^{M}.

formation for even Ba isotopes ($N = 72$, 74, 76, 78) has been found previously [19].

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