Study of γ-soft structure in Xe, Ba, Ce nuclei

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Introduction

The study of γ-soft or γ-rigid shape in light mass atomic nuclei is of current interest. Casten et al. [1] presented the behavior of γ-softness and triaxiality vis-a-vis O(6) symmetry of the Interacting Boson Model [2] for the $^{124–130}$Xe and $^{128–134}$Ba nuclei. The γ-unstable rotor of the collective Bohr-Mottelson model is equivalent to the O(6) symmetry and the axially symmetric deformed rotor to the SU(3) limit of IBM [2]. The light Ce isotopes with N<80 are also expected to exhibit γ-soft character [3]. There is also interest in low energy level structure of these nuclei for comparison with the predictions of the recently identified critical point symmetry E(5) [4, 5], which lies on the U(5) to O(6) transition path. The X(5) critical symmetry point lies on U(5) to SU(3) limit path [6].

In experiment, the low level structure of ^{128}Ba was investigated with the (p, t) reaction by Pascu et al. [7]. They also measured the 2n excitation cross section of the 0^+ states, which indicated this nucleus to lie close to O(6) symmetry. This work was extended to $^{132, 134}$Ba in Ref. [8]. Very recently, Li et al. [9] microscopically described the transition between the spherical U(5) symmetry to the γ- soft or O(6) shape in Ba and Xe nuclei and gave evidence of ^{130,132}Xe and ^{134}Ba nuclei as E(5) nuclei. In the present empirical work, we study the shape transition of light Xe, Ba and Ce isotopes in comparison with the predictions of the various symmetries for this region.

Result and Discussion

Level energy ratio $R_{4/2}$

The energy ratio $R_{4/2}$, a good measure of the shape deformation of the nucleus, is calculated by the relation $R_{4/2}=E_4^+/E_2^+$. This ratio is 10/3 for deformed SU(3) nuclei, 2.5 for O(6) or γ-unstable nuclei, 2.2 for the E(5) and 2.9 for X(5) symmetry. Figure 1 shows the variation of $R_{4/2}$ with neutron number N, and indicates that the deformation parameter $R_{4/2}$ in Ba and Ce decreases sharply from nearly X(5) value of 2.9 to the O(6) limit value of 2.5, which indicates that these nuclei have a shape change from β-soft deformed to γ-soft with increasing N. In figure 1, so far as $R_{4/2}$ is concerned, ^{130,132}Ba (N=74, 76) and ^{134,136}Ce (N=76, 78) data lie near the O(6) line, so that they are more likely to have γ-soft structure. ^{134}Ba lies close to E(5).

The variation of $R_{4/2}$ in Xe (Fig. 1) indicates that nuclei $^{118-126}$Xe lie in between the O(6) line ($R_{4/2}$=2.5) and the E(5) symmetry line at $R_{4/2}$=2.2, and that N=74-78 $^{128-132}$Xe isotopes are closer to the E(5) value, while lighter isotopes N=66-70 touch the O(6) line. Even the lightest Ba and Ce isotopes are below the SU(3) line, but touch the X(5) line. The different degree of deformability of Xe, Ba and Ce is also well evident here. With increasing proton number the value of $R_{4/2}$ increases much at Xe to Ba.

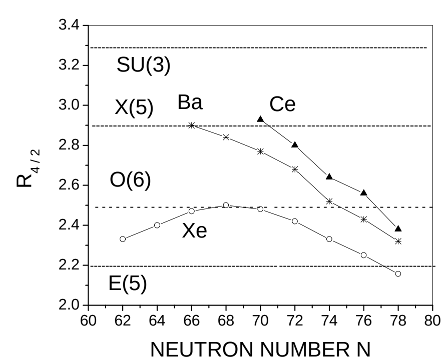

Fig. 1 Plot of $R_{4/2}$ vs N for Xe, Ba and Ce.

Asymmetry Parameter γ_0

The asymmetry parameter γ_0 can be determined [10] by the relation:

$$\mathrm{Sin}^2(3\gamma_0) = (9/8)\ \{1- (1- R_\gamma)^2/(1+ R_\gamma)^2\} \qquad (1)$$

Where $R_\gamma = (E_{2\gamma}/E_{2g})$.

This parameter also is a first good measure of the γ-softness of a nucleus [10].

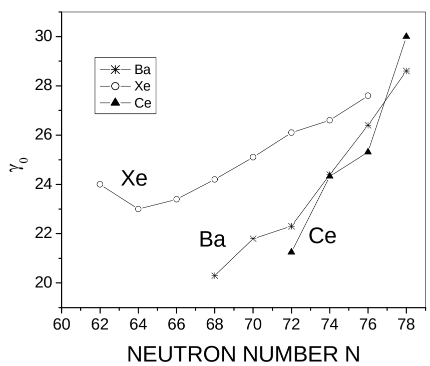

Fig. 2 Plot of asymmetry parameter γ_0 versus N.

Figure 2 shows the variation of γ_0 with neutron number N. In Xe nuclei, γ_0 first decreases for N=62, 64 (A=116, 118), then increases from N=66–76, which indicates that with increasing N, these nuclei have a shape change associated with increasing γ_0 asymmetry parameter up to 30°. The $^{116-120}$Xe nuclei, close to the minimum valley point, have least asymmetry as expected for mid-shell nuclei.

At N=68, 70 in Ba γ_0 is the least ≈ 20° and at N=72, Ce has lesser value of γ_0. There after it increases sharply with increasing N in Ba and Ce (Fig. 2), which again shows a shape change leading to increasing γ-softness. The shape features exhibited through the asymmetry parameter γ_0 agree with those indicated by the shape deformation parameter $R_{4/2}$. These observations for Xe and Ce are in consonance with the other features in these nuclei [5, 11].

Thus in the empirical study of light Xe, Ba and Ce nuclei, we get first useful information on their shape changes with proton number Z and neutron number N. More detailed information can be obtained through the phenomenological model IBM-1 [2] and the microscopic theory [3].

[+]Associated

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