Rotational states of odd Z rare earth proton emitter ^{131}Eu

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Introduction

Recent Observation of proton radioactivity and rotational bands in ^{131}Eu and ^{141}Ho with large deformations $\beta \approx 0.3$ and γ softness have already proven the study of excited states of deformed proton emitters a source of valuable information on the structure of proton decaying states and response of proton emitters on the stress of rotation. The rare earth nuclei below the N=82 shell closure form one of the few regions of the nuclear chart where nuclear shapes are expected to change rapidly with coexistence of oblate and prolate shapes in some nuclei. Thus a comprehensive study on the nuclear structure of ground as well as excited rotational states of proton rich ^{131}Eu in rare earth region is done to look for rapid shape phase transitions and large deformations expected in this region. While dealing with the excited nucleus using statistical theory [2], an important ingredient which decides the phase space available for the excited nuclei is nuclear level density is profoundly influenced by the temperature and angular momentum induced inrinsic structural changes. We observe these shape transitions to be associated with significant fluctuations in the level density parameter which was shown to be dependent on angular momentum in our earlier work [3] in agreement with the experimental observation [4]. The occurence of coexistence of these shapes at similar energies at a high angular momentum value is also speculated.

Brief description of work

We evaluate shapes and deformation of ^{131}Eu by combining classical collective properties of the liquid drop model with the quantum corrections due to shell effects via Strutinsky formalism adequately described in [2]. Excited states are treated using staistical theory. Nuclear shapes and deformation are traced by minimizing free energy (F = E-TS) w.r.t.deformation parameters β from 0 to 0.4 in steps of 0.01 and $\gamma$from -180^o (oblate with symmetry axis parallel to the rotation axis) to -120^o (prolate with symmetry axis perpendicular to rotation axis) and then to -60^o (oblate collective) to 0^o (prolate non-collective).

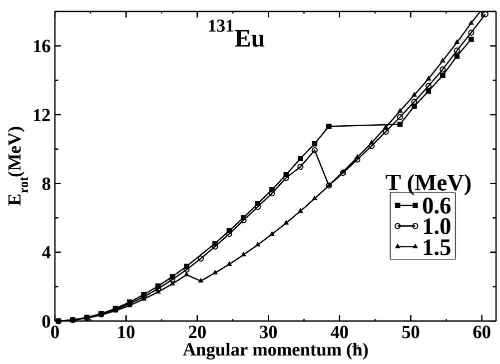

FIG. 1: Rotational states of ^{131}Eu for T-0.6, 1.0, 1.5 MeV.

Results and Discussions

Equillibrim deformation of ground state ^{131}Eu is β = 0.3 with prolate shape in agreement with the available experimental and other theoretical data. Moving towards higher N isotopes, the shape changes from prolate to triaxial. The excited rotational states are computed for angular momentum M=0 to 60$\hbar$ at T= 0.6, 1.0 and 1.5 MeV. Fig. 1 shows rotational states where a sudden kink in E_{rot} values indicates shape transition. Fig. 2 shows variation of β vs angular momentum where the shape transition from a rare shape prolate non-collective to usual classic shape phase

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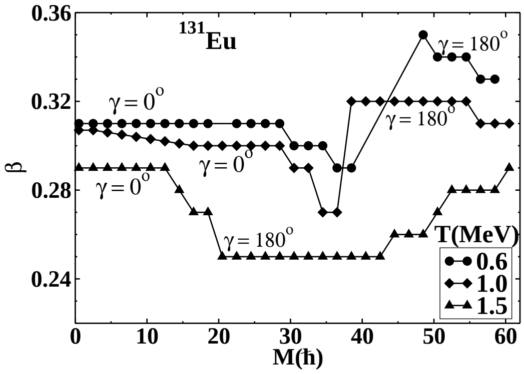

FIG. 2: Quadrupole deformation β vs. angular momentum. The shape transition from prolate non-collective(γ=0^o) to Oblate nc(-180^o) is seen

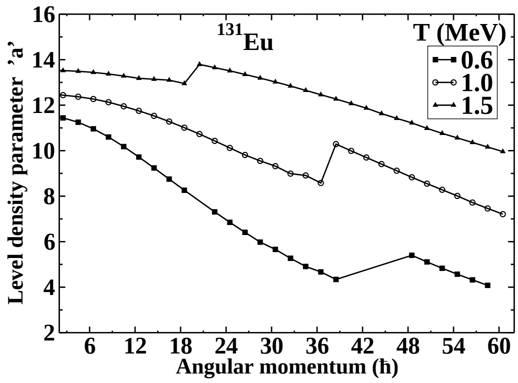

FIG. 3: Level density parameter fluctuating with shape transition at high angular momentum

of oblate non-collective at higher angular momentum is seen. As speculated in other works the ^{131}Eu is highly deformed in ground as well as excited state even at a high temperature of T=1.5 MeV. Level density parameter (Fig. 3 decreases as the rotational energy increases as expected but it shows significant deviation at the angular momentum where the shape transition has taken place. This proves that the rotation induced structural changes impact level density parameter signifcantly.

Conclusion

Excited rotational states of odd Z proton emitter ^{131}Eu in rare earth region show large deformation $\beta\approx$ 0.3 and prolate shape as expected. Shape transition from a rare shape phase of prolate non-collective to usual oblate non-collective is seen in excited rotational state which is associated with the significant fluctuations in the level density parameter which indicats a strong relation between the level density and the equillibrium shape of the nucleus and thus the precise knowledge of nuclear shapes may be useful in experimental measurements where level density is an important ingredient.

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