Deformation effects in one proton emitters

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Introduction

Our present understanding of the atomic nucleus is not complete since the nature of strong interaction which holds the nucleons together inside the nucleus is very complicated. The ultimate goal of nuclear structure physics is to account for the properties of complex nuclei in terms of the interaction between the nucleons. The knowledge concerning the nuclear structure has improved tremendously through the development of nuclear models. Simple mathematical assumptions and the underlying simple physical pictures have been successful in obtaining a systematic interpretation of enormous experimental data. Study of structural changes of nuclei at high excitation energy and large angular momentum has led us to a new phase in nuclear physics.

In addition to structure studies proton radioactivity has become a tag to study high spin states above the proton emission state. In fact, rotational states for the proton rich nuclei are studied using the recoil decay tagging technique. A spherical potential like the harmonic oscillator potential cannot give rise to the collective rotation, because the rotation of a quantum system around an axis of symmetry is not allowed. Thus a deformation term has to be added to the shell model potential to account for the deformation induced by the valence nucleons.

Theoretical formalism

The aim of the present work is to study the role of quadrupole deformation in proton rich nuclei, particularly with respect to odd Z nuclei within the region $50 < Z < 80$ near the proton drip line. The deformation is studied using triaxially deformed cranked Nilsson Strutinsky method with tuning. Some of the nuclei in the medium mass region are found to be proton emitters from the ground state with appreciable deformation. Energy calculations of the considered nuclei are calculated as a function of deformation β and non-axiality γ parameters by the tuned Strutinsky shell correction method.

Results and Discussions

The calculated ground state quadrupole deformation of the nuclei in $56 < Z < 83$ is calculated. The relatively high potential barrier enables the observation of ground state proton radioactivity less possible in the region $Z \leq 50$. This is due to the low Coulomb barrier [1]. Odd Z nuclei are found to be good proton emitters and much deformed than their even Z neighbours. This is due to the reason that pairing correlations are strongly reduced in odd Z nuclei and as a result the nucleus is driven towards larger deformation. Much stronger pairing in even Z nuclei results in almost spherical shapes. For $Z > 67$, the nuclei is moderately deformed. Strong deformation is observed in $62 < Z < 67$. A shape transition is observed for Ho, Tm, Lu, Ta nuclei (Z= 67,69,71,73). Re, Ir nuclei (Z=75, 77) exhibit a moderate deformation. Au nucleus shows a strong oblate deformation.

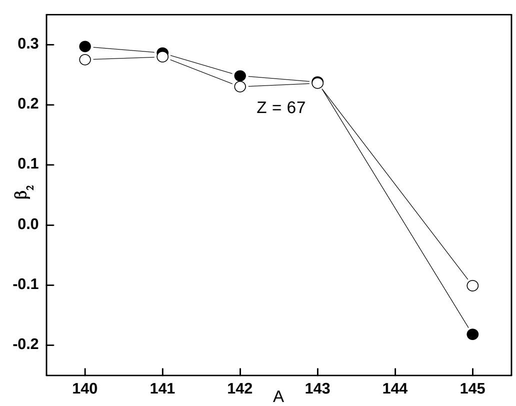

Fig.1 Quadrupole deformation of Holmium isotopes

In the fig.1 our calculated deformation values are compared with the values of Moller-Nix et al [2] and it is found that our values are in agreement with their values. In fig.1 the solid circle shows values from Moller and Nix and hollow circle data are calculated from cranked Nilsson Strutinsky shell correction method. Moreover significant normal quadrupole deformations are observed in the nuclei of Z = 63, 65 and 79. The variations in the calculated values of β when compared with Moller and Nix calculations are found to be negligibly small. Both oblate and prolate quadrupole deformed shapes are observed in the chosen region. The spherical shapes are found in the region Z = 71, 73 and 75.

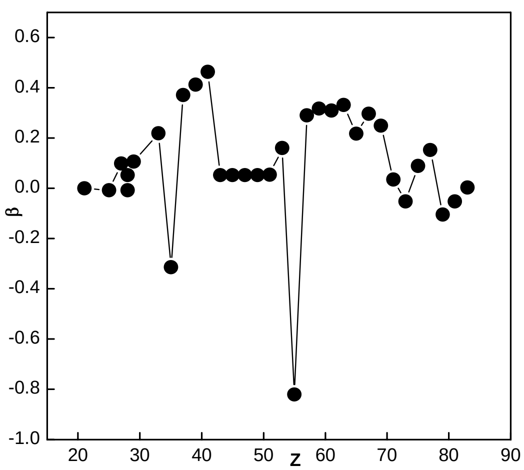

Fig. 2 Quadrupole deformation for various Z

Fig.2 shows the calculated ground state quadrupole deformations of the last proton bound nuclei for the single proton emitters. The oblate shape is found in the ^{138}Te and nuclei ^{132}Eu, ^{140}Ho, ^{145}Tm, ^{155}Lu, ^{159}Ta, ^{163}Re, ^{170}Ir and ^{174}Au are having normal prolate shapes in their ground state.

From the table, one could notice that normal deformations β_2= 0.10 exist in the chosen mass region. The table depicts the various single proton emitters having ground state quadrupole quadrupole deformation values. All are having normal deformation values and probability of shape co-existence is also feasible in the fertile region of Z=50 to 80. The accurate β values are studied through potential energy surface calculations.

Table: Calculated quadrupole deformation values of fertile single proton emitters

Nucleus	β_2	
	Calculated	Moller &Nix [2]
$^{109}I_{56}$	0.20	0.16
$^{112}Cs_{57}$	0.21	0.208
$^{113}Cs_{58}$	0.20	0.207
$^{146}Tm_{77}$	-0.18	-0.199
$^{147}Tm_{78}$	-0.19	-0.190
$^{150}Lu_{79}$	-0.16	-0.164
$^{151}Lu_{80}$	-0.16	-0.156
$^{156}Ta_{83}$	-0.05	-0.053
$^{157}Ta_{84}$	0.05	0.045
$^{160}Re_{85}$	0.10	0.080
$^{161}Re_{86}$	0.10	0.080
$^{165}Ir_{88}$	0.10	0.099
$^{166}Ir_{89}$	0.10	0.107
$^{167}Ir_{90}$	0.10	0.116
$^{171}Au_{92}$	-0.10	-0.105

In conclusion, the quadrupole deformation is a significant parameter which leads to radioactive decay by proton emission. Shape transitions observed in the Z=67, 69, 71, 73 nuclei could be studied in future in a detailed way.

References

[1] Lidia S.Ferriera, Miguel Costa Lopes, Enrico Maglione, Progress in Particle and Nuclear Physics **59,** 418 (2007).
[2] P.Moller, J.R.Nix, K.L.Kratz, At. Data Nucl. Data Tables **66,** 131 (1997).