Prolate non-collective shape - A rare shape phase around Z= 50

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Introduction

The search for rare shape-phase transition in hot and rotating nuclei is one of the very active field in Nuclear physics research. According to universally known features of the evolution of equillibrium shapes with temperature and spin, heating a deformed nonrotating nucleus leads to a shape transition from deformed to spherical at a certain temperature. At high temperatures T≈ 2 MeV, the shell effects melt and the nucleus resembles a classical liquid drop. Rotation of the hot nucleus generates an oblate shape rotating noncollectively. But it has been shown by A. Goodman that nuclei with two critical temperatures can rotate with a rare non-collective prolate shape phase which has been caused directly by rotation at angular momentum values around (5 - 30$\hbar$) which creates a residual quantum shell effect as shown by A. L. Goodman [1]. This hot prolate noncollective equillibrium phase had not been anticipated before the Ref. [1]. This unexpected prolate noncollective phase generated by rotation undergoes the expected transition to the oblate noncollective phase at high angular momentum values. Such a phase exists in a narrow domain bound by the two spin dependent critical temperatures. Search for such exotic shape-phase around Z=50 region is the aim of present work. We consider N = 60 isotones ^{108}Cd, ^{1098}In, ^{110}Sn.

Theoretical Formalism

We use statistical theory [2] of hot rotating nucleus combined with the macroscopic - microscopic approach adequately described in our earlier work [3]. The total energy of the excited nuclear system is computed by including stutinsky shell correction(δE), deformation energy (E$_{Def}$) and excitaion energy(E*) to the Liquid Drop Model energy(E$_{LDM}$). Then the free energy F of the system is computed and minimized w.r.t. deformation parameters β and γ

$$F(Z,N,T,M,\beta,\gamma) = E_{LDM}(Z,N)) \\ +\delta E_{shell}(\beta,\gamma) + E_{def}(\beta,\gamma) \\ +E^*(T,M,\beta,\gamma)) - TS(T,M,\beta,\gamma) \tag{1}$$

The Free energy minima gives the deformation and shape of the hot rotating nucleus.

Results and Discussion

Fig. 1 shows shape parameter γ vs. angular momentum (M) which shows the shape transitions taking place with angular momentum at a fixed T for ^{108}Cd, ^{109}In, ^{110}Sn. γ is shown to vary from prolate non-collective (0^o) to oblate collective(60^o) to prolate collective (-120^o) to oblate non-collective(-180^o). Other γ values correspond to triaxial shapes. Fig 1(a) shows γ variation vs. M($\hbar$) for ^{108}Cd. At low temperature T=0.6 MeV and at very low M, shape is triaxial(γ=130^o) . With increasing M, shape transition to uncommon prolate non-collective shape (γ=0^o) phase is observed and remains so upto M = 20$\hbar$ and then the shape transition to usual oblate non-collective (γ=180^o) shape takes place with increasing M. As T increases, shape transition to oblate non-collective phase takes at a lower M. At T = 1 MeV, the prolate non-collective shape phase is not at all seen and the shape is oblate for

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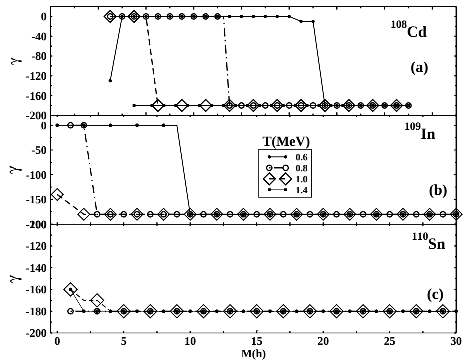

FIG. 1: γ variation vs. angular momentum M($\hbar$) for different T for (a) ^{108}Cd, (b) ^{109}In, (c) ^{110}Sn

all M values. With increasing Z as we approach shell closure deformation is decreasing and prolate non-collective shape phase is also diminishing (see Fig. 1 (b) for ^{109}In). At shell closure Z=50 (^{110}Sn), non-collective prolate shape phase does not exist at all and shape changes directly from triaxial to oblate non-collective which is the expected usual shape transition. The rare shape phase trasition is seen only in a specific range of nuclei and at certain excitation energy and angular momentum values only. In my recent work [4], I found this shape in drip line nucleus ^{94}Ag at M= 20 to 31 $\hbar$ and T = 0.6 to 0.8 MeV where we also observed proton radioactivity from a hot rotating nucleus. $^{105-122}$Te nuclei with Z=52, do not go through prolate shape phase at all as seen in our earlier work [3].

Thus we conclude that prolate non-collective shape phase is a rare shape phase which is seen under certain specific conditions of temperature and angular momentum only. Around Z =50 region, we found this phase in nuclei with Z $<$ 50 and is absent in Z $\geq$ 50. Further, this phase is seen only at temperature range T = 0.5 to 0.8 MeV with M = 5 to 30$\hbar$. At T $\geq$ 1 MeV, shape is mostly oblate non-collective. At M $\geq$ 30, shape transition from prolate non-collective to oblate non-collective is observed. Therefore the rare prolate non-collective shape phase is seen in a low temperature range of $\approx$ 0.5 to 0.8 MeV and M $\approx$ 5$\hbar$ to 30 $\hbar$ around Z=50 region. It is absent in higher T and M region.

Acknowledgments

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