Structural properties of some hot rotating rare earth nuclei

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Introduction

The shell model or independent particle model proposed by Mayer, Haxel, Jenson and Suess successfully explained the extraordinary stability of some nuclei which have magic numbered protons and neutrons

In the ground state most of magic numbered nuclei are spherical, prolate or possible triaxial and very few cases of really oblate nuclei have been found experimentally. Nilsson first proposed a deformed shell model for the nucleus considering it as spheroid that may either be prolate or oblate.

The effect of rotation on nuclear structure under extreme conditions of temperature and deformation is very important for understanding the intrinsic properties of nuclei.

At high temperatures the nucleus is highly deformed or super deformed and large amount of angular momenta are built up by alignment of single particle spins as well as by the collective rotation of the nucleus.

In this work, hot rotating rare earth nuclei $_{58}Ce^{136}$ and $_{60}Nd^{144}$ are studied and their structural properties are presented using statistical theory [1-3].

In our calculations the temperature is varied from 0.1 to 1 MeV and for each temperature the excitation energy, single particle level density parameter, nuclear level density parameter and the entropy are computed for various deformation parameters.

Free energy minimum

The free energy F = E – TS is minimized for various deformations. The deformation parameter δ is varied in the range of 0.0 to 0.6 in steps of 0.1 and θ is varied from 0^o to 60^o in steps of 20^o. The cranking frequency is taken to be zero.

The required angular momenta are generated by means of statistical theory by introducing the z projection of the angular momentum as a constant of motion through the Langrange multipliers corresponding to single particle spins. The levels generated are up to N = 8 are found to be sufficient for the range of temperatures used in this calculation.

The single particle level density parameter, the excitation energy, the nuclear level density parameter and entropy as a function of angular momentum and temperature for equilibrium deformation for nuclei $_{58}Ce^{136}$ and $_{60}Nd^{144}$ have been theoretically estimated and studied.

Results and discussion

In this work, the high spin behavior of the rare earth nuclei Cerium and Neodymium are investigated within the framework of statistical theory using a single particle level scheme as input [4].

From our calculations, it is observed that the free energy minimum for Cerium and Neodymium nuclei occurs at deformation $\delta = 0.1$ and $\theta = 0^o$.

This means that the shape of the Cerium and Neodymium nuclei is found to have prolate collective equilibrium shape and remains the same at all temperatures and spins.

Single particle level density parameter

The evaluation of single particle level density parameter is important since it plays a major role in determining the nuclear level density, which decides the phase space available in excited state. Bohr [5] has emphasized the importance of single particle level density parameter in the determination of the structural properties of nuclei.

The single particle level density parameter is calculated for equilibrium deformation of $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei for different spins and temperatures.

It has been evaluated from the theoretical studies that the value of single particle level density parameter of $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei increases with temperature and at large temperatures reaches a constant value of a $\approx$ A/10 as predicted experimentally.

The effect of rotation on single particle level density parameter is very much pronounced at low temperature. The single particle level density fluctuations are different for different angular momentum states at low temperatures because the shell structure plays a major role at low temperatures.

The nuclear level density parameter

The nuclear level density is calculated for equilibrium deformation of $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei for different spins and temperatures corresponding to the excitation energy.

It is found from the results that for $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei, as temperature increases the log nuclear level density also increases and for building up higher spins at given nuclear level density higher excitation energy is needed. But it is observed that there are no variations in log nuclear level density values for all angular momentum.

Excitation energy

The excitation energy is calculated for equilibrium deformation of $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei for different spins and temperatures. In this work it is to be noted that for $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei, as the temperature increases the excitation energy also increases.

So the excitation energy acts as a much more powerful smearing agent by spreading out nucleons above and below the Fermi surface.

Entropy

The entropy is calculated for equilibrium deformation of $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei for different spins and temperatures. It is understood from the calculations that for $_{58}Ce^{136}$ and $_{60}Nd^{144}$ nuclei, as temperature increases the entropy also increase.

However for higher temperatures the entropy value is found to reach a constant value. It is also predicted that the effect of angular momentum on entropy is highly negligible.

It has been evaluated that the angular momentum plays a major role in the single particle level density parameter, but angular momentum does not have any effect on entropy and log nuclear level density [6,7].

References

[1] K. Ilangovan and N. Arunachalam, Pramana, J.Physics. Vol.58 No.3 March (2002) 489.
[2] N.Arunachalam and K. Ilangovan, Phys.Rev. C52 (1995) 129.
[3] Jing-Ye-Zhang, Phys. Rev. C39 (1989) 714.
[4] N. Arunachalam and K.Ilangovan, Phys. Rev. C55 (1997)1
[5] A. Bohr, Nuclear structure, Benjamin, New York (1975) Vol II,84
[6] K. Ilangovan and N. Aruanachalam, Nucl. Phys. (India) 47B (2004) 114 and 116
[7] K. Ilangovan and N. Aruanachalam, Nucl. Phys. (India) 51 (2006) 326