g-factor and quadrupole moment measurements of 9/2⁻ and 23/2⁺ isomers in ^{129}Ba

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Introduction

Much attention has been focused on the neutron deficient nuclei in the $A\sim130$ mass region because of the coexistence of collective oblate shape and prolate shape, non collective oblate shape associated with band termination and band crossing etc. [1]. In this mass region, both protons and neutrons can occupy the unique-parity $h_{11/2}$ intruder orbitals which play an important role in driving the nuclear shape. The proton Fermi surface lies in the lower part of the $h_{11/2}$ subshell, which favors prolate shape, whereas the neutron Fermi surface lies in the middle or upper part of the $h_{11/2}$ subshell, which favors oblate shape. Thus, a coexistence of different shapes is expected in these nuclei because of opposite shape-driving forces of protons and neutrons in $h_{11/2}$ orbitals. The nuclear electromagnetic moment measurements are crucial to give unambiguous information about the configuration and the shape of the nucleus. Two isomeric band heads are observed in ^{129}Ba i.e., I=9/2⁻ ($T_{1/2}$=18ns) and I=23/2⁺ ($T_{1/2}$=63ns) [2]. Both the rotational bands belong to high-j neutron configuration having different deformation driving forces.

Experimental details

The isomeric states in ^{129}Ba were populated and aligned in the reaction ^{120}Sn(^{12}C,3n)^{129}Ba using 51MeV ^{12}C pulsed beam (250ns pulse interval) at the 15UD pelletron accelerator facility, Inter University Accelerator Centre, New Delhi. The target consisted of 450μg/cm^2 metallic ^{120}Sn deposited on iron in case of g- factor measurements and on Terbium (Tb) backing for quadrupole moment measurements. The excited ^{129}Ba nuclei recoil out of thin target and are stopped in their respective host materials. The Time Differential Perturbed Angular Distribution Technique (TDPAD) was used for both g-factor and quadrupole moment measurements [3].

In case of g-factor, the recoil nuclei experience internal magnetic field 85.5 KG in Iron [4]. No external magnetic field was applied to polarize the iron backing. The electric field gradient at barium in terbium is unknown, thus the ratio of the quadrupole moment for two isomeric levels has been observed. The γ-rays were detected by two NaI detectors positioned at angles 0° and 90° in a horizontal plane with respect to the beam at a distance 20 cm from the target. The data were collected in LIST mode with four parameters: the energy and time signals for each NaI detector. The time signal from the NaI detector was used to start the time to amplitude converter (TAC) and the stop signal was provided by the primary rf signal from the buncher.

Data Analysis

In the off-line analysis of list-mode data, two-dimensional matrices of energy versus time were formed for each detector. From these matrices time-gated energy spectra and energy-gated time spectra were created. For the 9/2⁻ state the 173keV γ- transition was analyzed, while in case of the 23/2⁺ isomer the analysis was done for the 473 and 779keV γ-transitions. The partial level decay scheme of ^{129}Ba is shown in fig.1.

After proper background subtraction and normalization, the time spectra were used to construct the appropriate experimental ratios, R(t) and $G_{22}(t)$ [5].
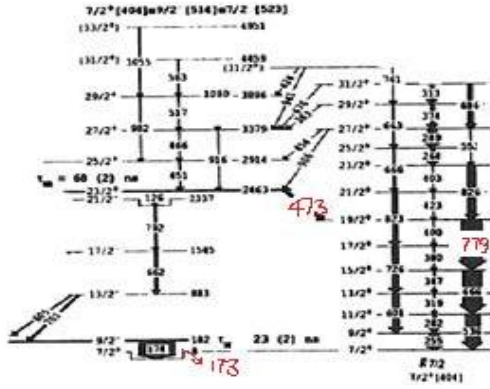

Fig.1 Partial level decay scheme of ^{129}Ba.

A. *g-* factors

To extract the g-factors from the time spectra, the modulation ratio function $R(t)$ was least squares fitted to the following theoretical function for the isomeric states at two sites,

$$R(t) = A_o + A_1\cos(\omega_L t) + A_2\cos(2\omega_L t),$$

The extracted values of g-factor using the relation, $\omega_L = \frac{g\mu_N H}{\hbar}$, are g($23/2^+$)= 0.186(15) and g($9/2^-$)= 0.211(16). The modulation function R(t) of the $23/2^+$ level is shown in Fig. 2. The g-factor of the isomeric states are approximately equal.
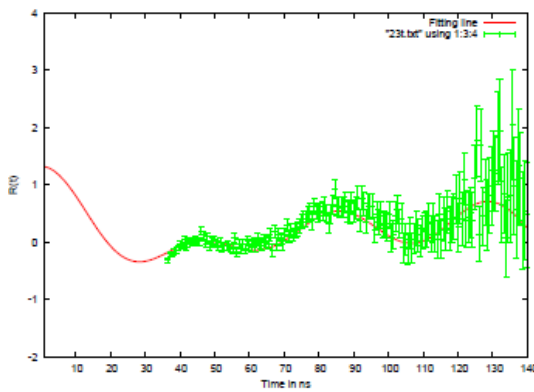

Fig.2 Spin rotation spectrum of $23/2^+$ state (^{129}Ba) in unpolarised iron.

B. Quadrupole moments

The experimental ratio functions $G_{22}(t)$ for each isomeric state were least-squares fitted to the following theoretical perturbation function for the two sites in a polycrystalline material [5] :

$$G_{22}(t) = \sum S_{2n}\cos(n\omega_{01} t)$$

The nuclei at the substitutional sites are characterised by the unique axially symmetric electric field gradient (efg) associated with the interaction frequency (ω_{01}). For $23/2^+$ state, the quadrupole interaction pattern is shown in Fig.3. The quadrupole interaction frequencies obtained for the isomeric states are, $\omega_o(9/2^-)$= 650Mrad/s and $\omega_o(23/2^+)$= 74Mrad/s. The interaction frequencies are used to derive ratio of spectroscopic quadrupole moments i.e. $Q_s(I=9/2^-)/Q_s(I=23/2^+)$ =1.24. This factor is independent of efg at the nucleus. It is interesting to note the reduction of the quadrupole moment of $23/2^+$ state. Assuming K to be a good quantum number the ratio of the intrinsic quadrupole moments is observed to be $Q_o(9/2^-)/Q_o(23/2^+)$ = 1.75.
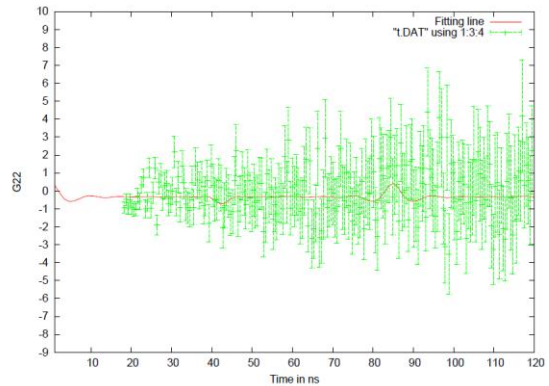

Fig.3 Quadrupole precession of the $23/2^+$ isomer of ^{129}Ba.

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