Complete spectroscopy of ^{146}Eu using alpha beam from VEC

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Introduction

Over the years the rare earth nuclei has provided a perfect ground for the exploration of different structural phenomena involving single particle and collective modes of excitation. However, the absence of the right combination of target projectile and the availability of suitable detection system had limited the complete information on the low lying structure of these nuclei. Though excited states have been studied from off-beam decay and in-beam experiments with light ion beams, the information on level lifetimes and specifically the transition moments have been very rare in almost all the nuclei.

The odd-odd nuclei, close to Z=64 and N=82 shell closure, have single particle structure involving the excitation of proton (neutron) particle (hole). This gives a high value for the magnetic moment of these states; on the other hand, the quadrupole moment carries very significant information regarding the collective excitation of the underlying core and its evolution with the increase in angular momentum. Perturbed angular correlation technique is one of the efficient techniques used for the study of quadrupole moments, in which the nucleus is doped in a suitable host material having required electric field gradient (EFG). However, many a times this kind of measurements become difficult because of the unavailability of i) appropriate host having an well known and substantial amount of EFG and ii) the appropriate detection system having good energy and timing resolution as well as high detection efficiency. The low lying structure of the odd-odd ^{146}Eu nucleus has been studied using off-beam decay measurements as well as single particle transfer reaction [1]. These levels have been developed up to 690.7 keV excitation, from ^{146}Gd electron capture decay, however the coincidence information among the cascade gamma rays are not complete and there is not much information on the spin and parity of the states. Limits have been given on the values of level lifetimes and there is practically no data available on the transition moments of the excited states. The 4^- ground state of this nucleus has been assigned to have a configuration of $(\pi d_{5/2})^{-1}(\nu f_{7/2})$ with a quadrupole moment of (-0.179) barn and magnetic moment of (+1.4) μ_N. We have already attempted the measurement of lifetimes of the excited states, which has been reported in ref. [2].

In the present work, we report a detailed study of the low lying excited levels of ^{146}Eu that includes the measurement of quadrupole moments by Integrated Perturbed Angular Correlation (IPAC) technique.

Experiment

The excited states of ^{146}Eu have been populated from the EC decay of ^{146}Gd ($t_{1/2}$ = 48 days), produced via ^{144}Sm (α, 2n) ^{146}Gd reaction with 32 MeV alpha beam from K=130 Cyclotron at Variable Energy Cyclotron Centre, Kolkata. Enriched ^{144}Sm targets have been used in the experiment which were 300 μg thick and was produced by electro-deposition of Sm_2O_3 on thin Al backing. The recoiling ^{146}Gd nuclei were deposited on Al and Tb catchers with the use of two different targets placed in the stack. The gamma rays de-exciting the excited states of ^{146}Eu have been detected offline with two single HPGe detectors of efficiency 10% and 23% respectively along with a segmented LEPS detector. The Al catcher was dissolved in acid and the Gd nuclei have been separated from Al matrix and then doped into rutile TiO_2 matrix by co-precipitation technique. Offline measurement was performed in singles and coincidence modes for both the Al and Tb catcher, the acid solution of the catcher and also the TiO_2 matrix for the

determination of angular correlation of gamma rays in different electronic environment.

Data Analysis and Calculation

The γγ coincidence information has been derived from the data taken with TiO_2 matrix as this will have no other activity except that of ^{146}Gd. Out of all the gamma rays reported in [1], only the presence of 114.0-, 114.7-, 154.7- and 268.9- keV gamma rays were observed with all the detectors but no indication of 576-, 383- and 421-keV gamma rays were found. The 76-keV γ ray has been found to be a background contamination. The 114.0 keV gate has been placed in the LEPS detector and the projected spectrum of the 10% HPGe is also indicative of the absence of the later set of γ rays in the level scheme of ^{146}Eu. The absolute intensities of the γ rays have been estimated from the total projection of all the detectors and the EC feeding to different excited levels of ^{146}Eu have been calculated from the intensity difference of the feeding and decay out γ rays. The multipolarities of different transitions have been obtained from their angular distribution in 90° and 180° detectors. Based on all these information, the level scheme of ^{146}Eu has been modified significantly and has been shown in figure 1.

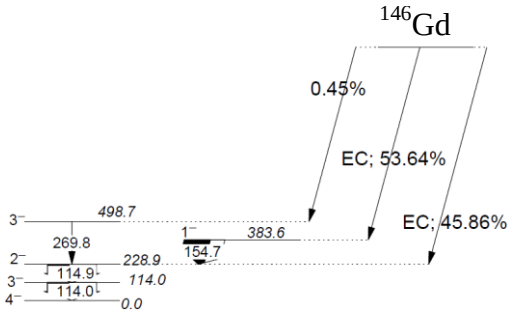

Fig. 1 Modified level scheme of ^{146}Eu

The angular correlation coefficient (A_2) has been extracted, for different sets of coincident gamma rays, in order to study the attenuation in angular correlation due to interaction of transition moments with the extra-nuclear fields [3]. The Al matrix has a cubic structure and is supposed to have no quadrupole interactions. However, the magnetic interaction due to the own free electron structure of Eu nuclei can be measured from the Al data. The quadrupole interaction has been looked into from the data taken with TiO_2 and Tb hosts. The liquid data has been used for getting the information on unperturbed correlation. In table I, the values of G_2s have been listed for different excited states, along with other relevant details.

Ab-initio electronic structure calculations based on density functional theory was performed for Eu doped TiO_2 system using WIEN2K code [3]. A super cell of TiO_2 having 2 X 2 X 3 units was considered and one of the Ti atoms was replaced by a Eu atom. Electric field gradient at Eu site in TiO_2 was found to be ~ 17 V/m^2. Since, Ti exists in 4^+ charge state in TiO_2, whereas Eu generally exist in 2^+ state, charge state considerations should be made. Calculations with charge state considerations and subsequent determination of quadrupole moment of excited states of ^{146}Eu is in progress.

Table I: *Calculated angular correlation parameter A_2 for liquid and TiO_2. Attenuation coefficient G_2 has been calculated comparing with the liquid value.*

E_{level} (keV)	E_{gate} (keV)	E_γ (keV)	A_2	G_2
114.0	114.9	114.0	0.0416(8) Liquid	
114.0	114.9	114.0	0.0363(7) TiO_2	0.87(3)
230.0	154.7	114.9	0.0300(6) Liquid	
230.0	154.7	114.9	0.0267(5) TiO_2	0.89(3)

References

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