Lifetime measurement of the unnatural parity states of ^{49}V

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Introduction

Nuclei belonging to the $1f_{7/2}$ subshell provide a wonderful opportunity to study the interplay between single particle and collective types of excitations. As the number of nucleons increases in this subshell, the single particle nature decreases and a collective nature emerges. This trend continues till the middle of the subshell, after which it reverses [1]. The nucleus ^{49}V, thus, is an excellent candidate to study this interplay, as it has nine nucleons (3*p*, 6*n*) in its $1f_{7/2}$ subshell.

The level scheme of ^{49}V is quite well known. The most recent study on this nucleus was carried out by Y. Sapkota *et al.* [1] for the natural (negative) parity levels. They measured the level lifetimes and carried out a study of the structural evolution of this nucleus along its various bands. The presence of a new *K* band was also established in the work. However, the spin-parities of most of the unnatural (positive) parity levels are still unconfirmed, and their level lifetimes have also not been reported yet.

So, in this work, we have focused on the unnatural parity levels of the nucleus ^{49}V. We measured the level lifetimes for few levels using the Doppler shift attenuation method. In addition, the spin-parity of existing levels were also measured and confirmed.

Experimental Details

High spin states of ^{49}V were populated through the ^{48}Ti(^{4}He,2*np*)^{49}V fusion evaporation reaction at E_{lab}= 48 MeV. The ^{4}He beam was provided by the K-130 Cyclotron at the Variable Energy Cyclotron Centre (VECC) Kolkata. The experiment was carried out on a self-supported 12.4 mg/cm^2 thick natural Ti target, where close to 95% of the recoils stopped within the target. The multi-detector INGA setup comprising of six Compton suppressed clovers [125°(2), 90°(3), 40°(1)] and two LEPS (90° and 40°) were used to detect the γ rays. The data were recorded in list mode using 12-bit PIXIE-16 digitizers (XIA LLC). The raw data were then sorted using the program IUCPIX [2] to generate symmetric and asymmetric matrices, which were subsequently analyzed using the program INGASORT [3]. The energy calibration was done using ^{152}Eu, ^{133}Ba, and a few online γ's. The relative efficiency calibration of the clovers was performed with ^{152}Eu and ^{66}Ga radioactive sources.

Result and Discussions

The positive parity levels of ^{49}V were investigated through coincidence relationship and relative intensity measurements using a 90° vs 90° symmetric matrix, taking proper care of the angular distributions of dipole and

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quadrupole transitions. The total projection spectrum thus obtained is shown in Fig. 1. The existing level scheme was verified and two new transitions were identified and placed in it. A relevant portion of the level scheme is shown in Fig. 2, where the new transitions are marked by asterisks.

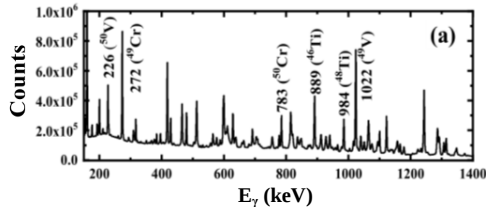

Fig.1 A total projection spectrum of γ rays emitted by the different nuclei formed in the present experiment. Only the strongest ground state transitions of the populated nuclei are marked.

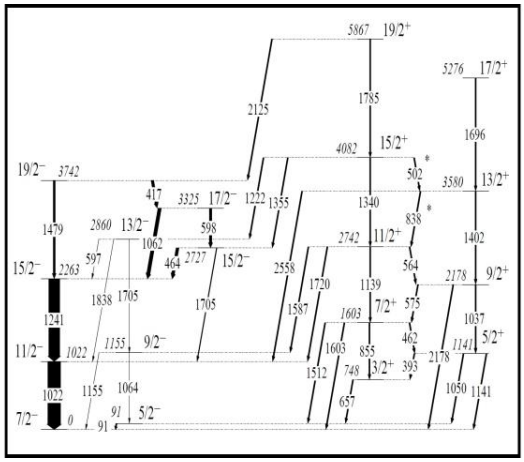

Fig.2 A partial level scheme ^{49}V.

Directional correlation (DCO) and polarization (IPDCO) measurements were carried out using angle-dependent asymmetric matrices and the spins and parities of all the levels were confirmed.

Doppler shifted line shapes were also observed for a few transitions in the spectra. The lifetimes of four new levels and two earlier reported levels were measured from these spectra using the Doppler shift attenuation method. A modified version of the computer code LINESHAPE [4] was used to measure these level lifetimes by performing line-shape analysis. The fitted line-shape spectra obtained in the present analysis for three transitions out of six (one earlier reported-1037 keV and two newly measured-1402, 1696 keV) are shown in Fig. 3. The measured lifetimes are of the order of picosecond, consistent with those of the natural parity states [1].

The structural evolution of the unnatural parity bands shall be studied by measuring the transition probabilities. An investigation of the interplay in ^{49}V shall also be approached from a microscopic point of view using large basis shell model calculations.

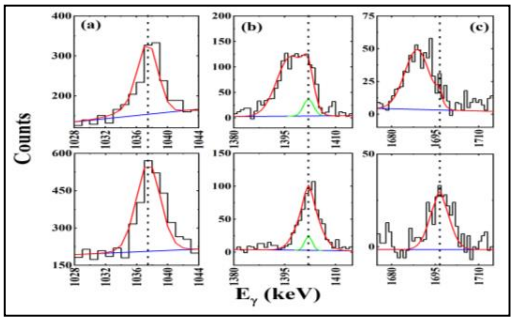

Fig.3 Experimental (black) and simulated (red) line-shape spectra are shown for the (a) 1037, (b)1402, (c) 1696 keV transitions for the angles 125º (top) and 90º (bottom). The extra stopped peaks are shown in green.

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