Lifetime measurement of nuclear levels of ^{37}Ar

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Introduction

Spectroscopic study in upper *sd* shell nuclei gives us a unique opportunity to investigate the interplay between single particle and collective excitations experimentally and interpret them theoretically using large basis shell model calculations. The coexistence of single particle and collective excitations have already been observed in many upper *sd* shell nuclei like ^{33}S, ^{34,35}Cl, ^{36,38}Ar, ^{40}Ca etc. [1]. Few of them have even superdeformation at higher excitation energy. Primarily, mode of nuclear excitation has been identified from their level structure. But in order to confirm the excitation mode, the information on the level lifetime is required. If the level lifetime is known, one can then extract the transition strengths, quadrupole moment (Q_t), deformation parameter (β), major to minor ratio (X) etc. and are therefore important for studying shape changes. The presence of collectivity in these upper *sd* shell nuclei has been established from their measured level lifetimes.

^{37}Ar is an even-odd nucleus in upper *sd* shell region. The superdeformed and normal deformed bands in ^{36}Ar and ^{38}Ar, respectively, have already been observed. From shell model calculations, it has been found that both of these bands are generated with 4p-4h excitations. ^{37}Ar is one neutron away from both ^{36}Ar (^{37}Ar - 1n) and ^{38}Ar (^{37}Ar + 1n). So, one may expect collectivity generated from multi particle-multi hole excitation at higher excitation energy in ^{37}Ar. ^{37}Ar was substantially investigated by light ion induced reactions in earlier days [1]. However, only a few heavy ion induced reaction data are available for ^{37}Ar [2,3]. Previously, E. K. Warburton et al [2] have measured the level lifetimes of a few excited levels up to 7 MeV in ^{37}Ar using RDM method. In our earlier work [4], we have extended the level scheme of ^{37}Ar up to 13 MeV. During our analysis, we have observed lineshape for a few transitions in ^{37}Ar (Fig-1). So, in the present work, we have measured the level lifetime for a few transitions and compared them with shell model calculations.

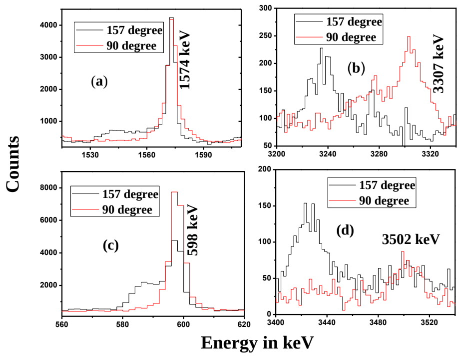

Fig-1: The shifted and un-shifted component of (a) 1574- (b) 3307- (c) 598- (d) 3502 keV transitions in ^{37}Ar.

Experimental Details

^{37}Ar was populated through ^{27}Al(^{12}C, np) fusion evaporation reaction with 40 MeV ^{12}C beam at TIFR, Mumbai. The target ^{27}Al of thickness 0.5 mg/cm^2 was deposited on ^{197}Au backing of thickness 10 mg/cm^2. A multidetector array, comprising of fifteen Compton suppressed clover detectors, those were mounted at six different angles i.e., 157^0(3), 140^0(2), 115^0(2), 90^0(4), 65^0(2), and 40^0(2), was used to detect the emitted gamma rays. All the relevant details of the experiment and data acquisition system have been discussed in ref. [4,5].

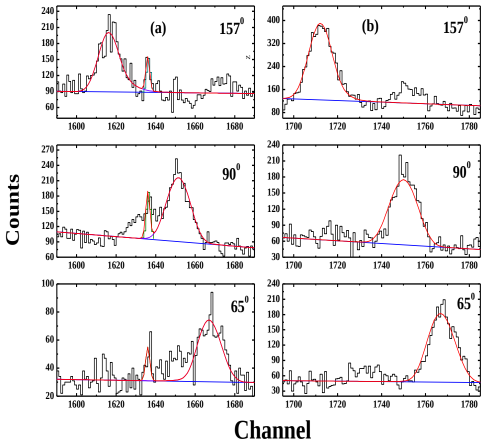

Fig-2: Experimental (black) and simulated (red) lineshape spectra are shown for (a) 3307 keV and (b) 3502 keV transitions for different angles as mentioned in the figure. The blue lines indicate the background.

Results and Discussion

The energy spectra for γ transitions from 5618, 7013, 7269, 9091, 9102 and 10574-keV levels in ^{37}Ar were totally shifted indicating the presence of a very short half-life. In the present work, we have extracted the lifetimes of a few of these levels by using the modified version of the computer code LINESHAPE [6]. The angle-dependent (157^0, 90^0 & 65^0) lineshape spectra are generated by putting a gate below the transition of interest. In LINESHAPE, we have first simulated the slowing down histories, in the ^{27}Al target with Au backing, of the 50000 ^{37}Ar recoiling nuclei with a time step of 0.0007 ps. The detector geometry was also taken into account. In the next step, using the stopping powers and the calculated velocity distributions of the recoils, a line shape for each decay time was obtained. In the final step, using the χ^2-minimization technique, the theoretically generated line shapes were fitted to the experimental ones to extract the level lifetime (Fig. 2). In this measurement, shell-corrected Northcliffe and Schilling stopping powers [7] were used for calculating the energy loss of ions in matter.

In this abstract, we have reported the lifetimes of 7013 and 10574 keV levels (Fig.2 and Table-1). No direct feeding transitions to these levels have been observed. So we have only estimated the upper limit of their lifetimes. We have listed our results with the theoretical values obtained from shell model calculation in Table-1. The extracted lifetime of 7013 keV level has good agreement with the theoretically calculated lifetime. However, for 10574 keV level, the measured lifetime is ~ 3 times shorter than its theoretical value. The result also shows the presence of substantial deformation / collective mode of excitation at these excitation energies.

Table-1: Comparison of lifetimes (τ in fs) from experiment and theory.

E_x (keV)	**E_γ (keV)**	**τ in fs**		**Q_t (eb)**	**β**	**X**
		Expt.	**Theo**			
7013	**3307**	**<30**	**30**	**0.62 (4)**	**0.26 (2)**	**1.28 (2)**
10574	**3502**	**<35**	**92**	**0.41 (1)**	**0.18 (1)**	**1.18 (1)**

The lineshape analysis will be presented for the other levels to understand the evolution of collectivity with angular momentum and excitation energy.

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