Spectroscopic study of ^{49}Ti

Sahil Kumar[1], Nikki Kumari[1], D. Majhi[1], A. Bera[1], Y. Sapkota[2], Rozina Rahaman[1], Abhijit Bisoi[1*], Anik Adhikari[1], Arkabrata Gupta[3], H. Ghosh[1], S. Sarkar[1], Dibyadyuti Pramanik[4], Ananya Das[5], Sangeeta Das[1], S. Ray[6], Sathi Sharma[7], Shabir Dar[8,9], S. Nandi[8,9], S. Bhattacharya[8,9], T. Bhattacharjee[8,9], G. Mukherjee[8,9], S. Bhattacharyya[8,9], S. Samanta[10], S. Das[11], S. Chatterjee[11], R. Raut[11], and S. S. Ghugre[11]

[1]*Indian Institute of Engineering Science and Technology, Shibpur, Howrah 711103, India*

[2]*Department of Physics, Dudhnoi College, Dudhnoi, Goalpara, Assam 783124, India*

[3]*Institute of Engineering and Management, UEM, Kolkata 700160, India*

[4]*Haldia Institute of Technology, Haldia, 721657, India*

[5]*Dream Institute of Technology, Samali, Kolkata 700104, India*

[6]*Amity Institute of Nuclear Science and Technology, Amity University, Noida 201313, India*

[7]*Department of Physics, Manipal University, Jaipur 303007, India*

[8]*Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata 700064, India*

[9]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai 400094, India*

[10]*Adamas University, Kolkata 700 126, India*

[11]*UGC-DAE Consortium for Scientific Research, Kolkata Centre, Kolkata 700098, India*

. **Email: abhijitbisoi@physics.iiests.ac.in*

Introduction

The study of the $1f_{7/2}$-shell nuclei gives us a unique opportunity to investigate the interplay between single particle and collective excitations. The collectivity in the ground state of the $1f_{7/2}$-shell nuclei increase towards the middle of the $1f_{7/2}$-shell and start to disappear rapidly when approaching the doubly magic nucleus ^{56}Ni as nuclei evolve towards a spherical shape [1]. Strong collectivity near ground state, rotational like band structure, shape transitions towards triaxial and non-collective deformations have been observed in a few nuclei around ^{48}Cr [2]. Theoretical investigations through large basis shell model (LBSM) calculation have been performed successfully to interpret the experimental data [3].

Experimental investigations on the $1f_{7/2}$-shell nuclei have been going on for the last few decades. But still, lack of experimental data has been found for a few nuclei and need experiments to explore their structure at high spin. In this present work, we concentrate on ^{49}Ti, one of the neighboring nuclei of ^{48}Cr. The spectroscopic information of ^{49}Ti is very limited. The level scheme of ^{49}Ti was extended only up to 7 MeV and the spin and parity of the high spin levels were assigned tentatively [4,5]. The lifetime of most of the high spin levels were either not measured or reported at their upper limit only [6]. So, our primary motivation is to expand the level scheme of ^{49}Ti and measure the lifetime of a few levels using lineshape analysis. Finally shell model calculation will be performed to interpret the observation.

Experimental Details

High spin states of ^{49}Ti were populated through the ^{48}Ti(^{4}He,2*pn*) ^{49}Ti fusion evaporation reaction at 48 MeV. The experiment was carried out at Variable Energy Cyclotron Centre Kolkata on a self-supported 12.4 mg/cm^2 thick natural Ti target. The INGA setup consisting of six Compton suppressed clovers and two LEPS were used to detect the γ rays. The data were recorded in list mode using 12-bit PIXIE-16 digitizers (XIA LLC) and then sorted using the program IUCPIX [7] to generate symmetric and asymmetric matrices, which were subsequently analyzed using the program INGASORT [8].

Results and discussion

The level scheme of ^{49}Ti was investigated through the coincidence relationships and the relative intensities of the gamma transitions. A typical gated spectrum of ^{49}Ti is shown in Fig. 1(a). We have extended the level scheme up to 7.6 MeV by adding 5 new levels and 5 transitions. M. Niikura et. al., [4] added 2660 keV, a new gamma in the existing level scheme and placed it above 1092 keV transition. In the present work, 2660 keV transition is not found in 1092 keV gated spectrum (Fig. 1(b)). Apart from that, we have found a 2654 keV transition which is in coincidence with 1543, 963 and 785 keV transitions but not in coincidence with 1092 keV transition. So, we have placed 2654 keV transition accordingly in the level scheme. The spin and parity of 2721 keV level was earlier reported as ($11/2^+$,13/2,$15/2^-$) [6]. In the present work, the measured R_{DCO} of 1178 keV transition, obtained from 1543 keV gated spectrum (Fig. 2) is 0.92(15), and has positive Δ_{IPDCO} value. We have therefore assigned the spin and parity of 2721 keV level as $11/2^-$. The spin and parity of other levels are confirmed or assigned in the present work. Spectroscopic properties of the 904 keV level could not be studied due to its poor statistics. We have, therefore, placed 904 keV in the level scheme tentatively (Fig. 2).

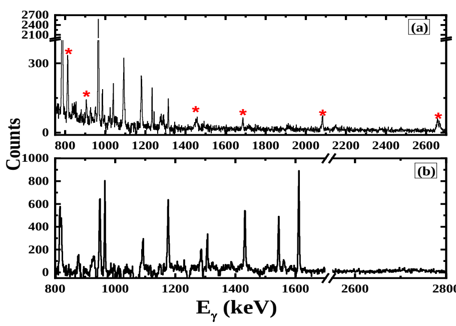

Fig. 1:(a) 1543 and (b) 1092 keV gated spectra. New transitions are marked with red acentric.

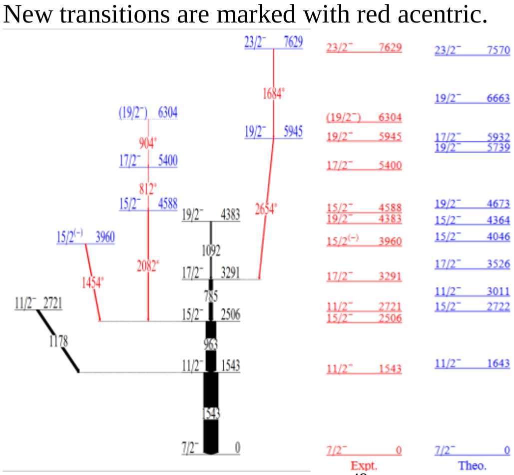

Fig. 2: Partial level scheme of ^{49}Ti (Left). New transitions (red) are labeled with *. A comparison between the experimental and shell model level energies is shown on the right.

The lifetime information of the levels in ^{49}Ti is very limited. Except for the 1543 keV level, only the upper limit or ranges of lifetime of the existing levels are available [6]. We have observed Doppler shifted peaks for a few transitions viz. 785, 812, 1092, 1178, and 1454 keV transitions (Fig. 3). Lineshape analysis will be therefore carried out to measure the lifetimes of these levels.

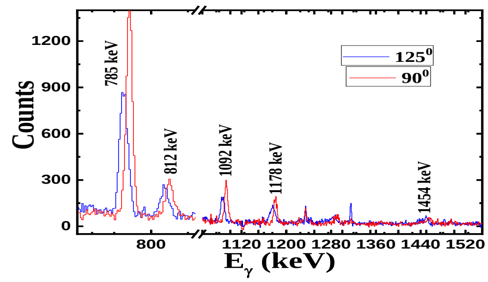

Fig. 3: 1543 keV gated spectra for two different detector angles.

We have performed large basis shell model calculation using the code NuShellX [9] and KB3G [10] interaction. The calculation has been performed without any particle restriction and the calculated energies are agreed well with their experimental energies (Fig. 2). Now, transition probabilities, moments, spectroscopic factors, etc. will be carried out to understand the evolution of shapes with angular momentum in ^{49}Ti.

Acknowledgments

The authors sincerely thank the accelerator staff of VECC, Kolkata for a nearly uninterrupted beam and also thank the INGA (partially funded by the Department of Science and Technology, Government of India) collaboration.

References

[1] S. M. Lenzi et.al., Phys. Rev. C **56**, 1313 (1997).
[2] F. Brandolini *et al.*, Nucl. Phys. A **642**, 387 (1998); C. E. Svensson et.al., Phys. Rev. C **58**, R2621 (1998).
[3] F. Brandolini et.al., Phys. Rev. C **71**, 054316 (2005).
[4] M. Niikura et.al., Eur. Phys. J. A **42**, 471–475 (2009)
[5] M. Behar et.al., Nucl. Phys. **A 366** (1981) 61-67
[6] https://www.nndc.bnl.gov
[7] S. Das *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **893**,138 (2018).
[8] R. Bhowmick *et al.*, Proc. DAE-BRNS Symp. Nucl. Phys. (India) B **44**, 422 (2001).
[9] NuShellX@MSU, B. A. Brown et.al., http://www.nscl.msu. edu/~brown/resources/resources.html; NuShellX, W. D. M. Rae, http://www. garsington.eclipse.co.uk/
[10] A. Poves, J. Sánchez-Solano, E. Caurier, and F. Nowacki, Nucl. Phys. A **694**, 157 (2001).