Lifetime measurement of low lying states of ^{27}Si

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Introduction

Properties of the excited states in ^{27}Si above the proton emission threshold (7463.32 keV) [1] are relevant for studies related to the abundance of ^{26}Al in the Milky Way. The sub-threshold states, most of which have been studied long back [2] are also significant while studying branching of the particle channels in the ^{12}C + ^{16}O fusion process [3] and isospin-symmetry in nuclei [4].

In the present work, our primary motivation is to study the low lying isobaric analogue states (IAS) of $^{27}Si(T_z = -1/2)$ populated through charge - exchange reaction (p, n) from its mirror partner $^{27}Al(T_z = 1/2)$. There are several advantages of using proton induced reactions for studying low-lying states. Despite having low recoil velocities (here in case of ^{27}Si ion, v/c is $\simeq 0.003$), excited states of the residual nuclei are populated non-selectively . One can also specifically excite a few levels of interest and minimize the side feeding effects, which is advantageous while determining the level lifetimes.

Experiment and Analysis

The experiment was performed at VECC, Kolkata using K=130 Cyclotron during the recent campaign of Indian National Gamma Array (INGA). Natural ^{27}Al target was bombarded with 10 MeV proton beam. The target was 35 mg/cm^2 with 0.3 mm thick Ta backing. The INGA@VECC2018 consisted of 6 Clover detectors with 4 detectors at 90^o and two detectors at 125^o and one LEPS detector at 40^o. Digital acquisition system PIXIE-16 acquired data both in singles as well as in coincidence mode [5]. Three channels were dominant in this reaction. They are - $^{27}Al(p, p'\gamma)^{27}$Al, $^{27}Al(p, n\gamma)^{27}$Si and $^{27}Al(p, \alpha\gamma)^{24}$Mg. In case of ^{27}Si, excited states upto $\simeq$ 3 MeV were populated (Fig. 1).

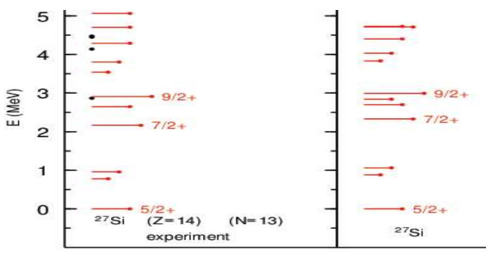

FIG. 1: Comparison of experimental [2] and theoretical level scheme of ^{27}Si till $\simeq$ 5 MeV.

To calibrate the experimental spectrum at higher energy and determine detector efficiency, ^{66}Ga was produced by bombarding natural Zn with proton beam. ^{66}Ga has a half life of 9.49 h and its decay spectra consists of several gamma rays with energies ranging from 0.8 MeV to 5 MeV. The calibration and efficiency of the Clover detectors at each

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TABLE I: Experimental lifetimes and reduced transition probabilities of excited levels in ^{27}Si are compared with theory. B(E2)'s in units of e^{2}fm^4 (B(M1)'s in μ_N^2) are shown in the first (second) line for each level. Experimental B(E2) and B(M1) values are determined with mixing ratios from [2]. These values are calculated only for the mean value of lifetimes.

E_γ		Half-life(fs)		Transition probability		
(keV)	I^π	Pres.	[4]	Pres.	[4].	Theo.
2163	$7/2_1^+$	>21	53(9)	<127.46	40	43.90
				<0.22	0.09	0.08
1690	$5/2_2^+$	>28	37(16)	<11.09	8	35.03
				<0.32	0.25	0.44
746	$9/2_1^+$	>54	75(14)	-	-	13.46
				<0.15	<0.46	0.10

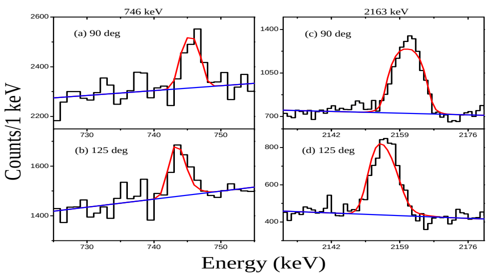

FIG. 2: Typical lineshape fits of two different gammas of ^{27}Si at two different angles. Black line connects the experimental data, red line is the lineshape fit and blue line is background.

angle were obtained using ^{152}Eu, ^{66}Ga decay data upto 5 MeV. The PIXIE-16 digitizer data was sorted using IUCPIX sorting programs [5]. Analysis was done using INGASORT [6] software. The lifetimes of the excited states were determined (Fig. 2) using LINESHAPE code [7]. We are only reporting the results without any side-feeding corrections to get a limiting value.

Theoretical calculations, Results and Discussions

Shell model calculations with OXBASH code [8] have been performed to calculate the energy spectra and transition rates. The *sd* valence space with ^{16}O core and USDB interaction are used. The transition probabilities are calculated with effective charges e_p=1.35e and e_n=0.35e, respectively, and standard values of intrinsic moments. In Fig. 1, the theoretical prediction of the energy spectra compare quite well with experiment. The transition probabilities (Table 1) also agree well in most cases. However, the large deviation of the theoretical reduced transition probabilities corresponding to 1690 keV transition needs special attention. The present experimental limits on lifetimes indicate necessity of including side-feeding corrections.

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