

DSAM Lifetime Measurements in ^{140}Sm

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Abstract: High spin states of ^{140}Sm have been populated using the $^{116}\text{Cd} (^{28}\text{Si}, 4n) ^{140}\text{Sm}$ heavy ion fusion evaporation reaction at beam energy of 128.7 MeV. Lifetimes of states have been measured using DSAM method. Lifetime and B(E2) values of quadrupole bands in ^{140}Sm are $2.47^{+0.1}_{-0.1}$ ps, $0.034^{+0.001}_{-0.001}\text{e}^2\text{b}^2$ and $1.32^{+0.07}_{-0.07}\text{ps}$, $0.031^{+0.002}_{-0.002}\text{e}^2\text{b}^2$ respectively

Keywords: INGA, Heavy ion fusion evaporation, DSAM.

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1. Introduction

In even-even nuclei with mass $A \sim 140$, the alignment of proton and neutron quasiparticles in the $h_{11/2}$ orbitals generates low-lying 10^+ states which are in many cases isomeric. These excitations have been observed in the $N=78$, $^{140}\text{Sm}^1$ and $^{142}\text{Gd}^2$ nuclei. In the rare-earth region, high-j $h_{11/2}$ unique parity orbital is accessible to both neutron and proton excitation. In nuclei for this region, both proton and neutron are at same high-j shell, i.e. $h_{11/2}$ orbitals which give us opportunity to study the role of p-n interaction and its influence on both collective as well as single particle motion.

For $N = 78$ nuclei e.g. ^{142}Gd , ^{138}Nd , $^{136}\text{Ce}^{2,4}$, the active orbitals for protons and neutrons are $h_{11/2}$, $d_{5/2}$ and $g_{7/2}$. At low spins, the presence of isomers based on simple particle-hole excitations helps to establish the active quasiparticle configurations and test the suitability of various nuclear potentials. The neutron-deficient rare earth nuclei are an ideal testing ground for theoretical models and the effective nucleon-nucleon interactions that they employ. Previously ^{140}Sm was studied by S. Lunardi et al.¹ using $^{114}\text{Cd} (^{30}\text{Si}, 4n\gamma) ^{140}\text{Sm}$ reaction at 130 MeV and a cascade of $\Delta I=2$ bands based on

10^+ isomer was reported. An interpretation in terms of the coexistence of the two shapes, which are supposed to have different quadrupole deformations, has been suggested. Lifetime measurements in the collective sequences found above the two isomers can give a more definite answer to the question of the coexistence of different nuclear deformations. Earlier, M. A. Cardona⁵ performed lifetime measurements by means of the recoil-distance Doppler-shift technique, using a precision plunger apparatus. The lifetimes of a few states above 10^+ are reported by this method. Excited levels in ^{140}Sm were populated using the $^{106}\text{Pd} (^{37}\text{Cl}, p2n) ^{140}\text{Sm}$ reaction at a bombarding energy of 143 MeV. In the present work, lifetimes of few states have been measured using DSAM method.

2. Experimental Details

In the present work, high spin states of ^{140}Sm have been populated using the $^{116}\text{Cd} (^{28}\text{Si}, 4n) ^{140}\text{Sm}$ heavy ion fusion evaporation reaction at beam energy of 128.7 MeV provided by pelletron linac at TIFR, Mumbai. Target used in experiment was 1 mg/cm^2 thick ^{116}Cd backed with 6 mg/cm^2 gold foil. Compound nucleus recoil velocity was 1.9% velocity of light and the recoil energy was 25 MeV.

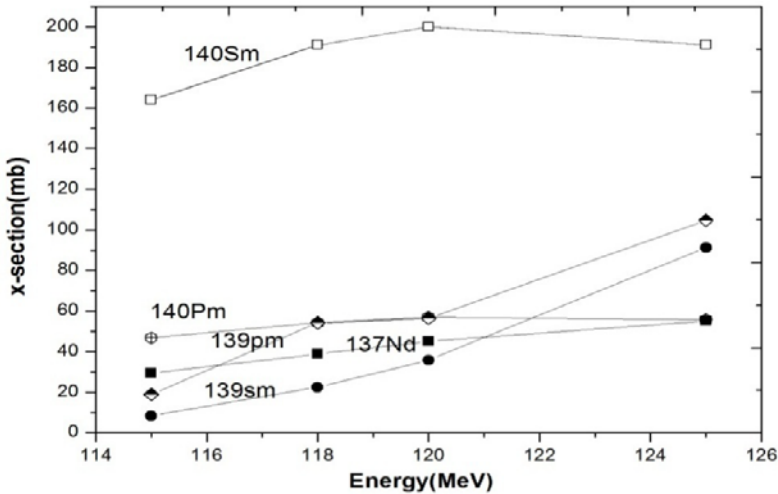


Figure 1: Various channels populated in $^{116}\text{Cd} + ^{28}\text{Si}$ reaction.

Indian National Gamma Array (INGA)⁶ consisting of nineteen Compton suppressed Clover detectors at angle of $-23^\circ, -40^\circ, -65^\circ, 90^\circ, 65^\circ, 40^\circ, 23^\circ$ were used to detect de-exciting gamma rays. Total numbers of events recorded

were 500 million. The cross-sections were calculated using CASCADE⁷ for various channels populated in this reaction are shown in Fig.1.

3. DSAM Lifetime Measurements

Lifetimes of states have been measured by Doppler shift attenuation method. For this, asymmetric matrices were constructed by keeping 65° detector on one axis and the rest of the detectors on other axis for forward analysis. For backward line-shape analysis, $-65^\circ(115^\circ)$ detectors were kept on one axis and the rest of the detectors on another axis. Similar matrices were constructed for detectors placed at $+40^\circ$ and -40° . To check the contamination in forward and backward data, matrices were constructed for 90° versus all detectors. For line-shape analysis of the transitions, the LINESHAPE program⁸ was used. The program takes into account the energy loss of the beam through the target, the energy loss and angular straggling of the recoils through the target and the backing. For the energy loss, we used the shell-corrected Northcliffe and Schilling stopping powers. The value of the time step and the number of recoil histories were chosen to be 0.001 ps and 5000 respectively. Apart from the mass and density profile of projectile and target, the inputs of code DECHIST and HISTAVER are: target to detector distance which is 25 cm in our case and radius of Ge detector which is 6 cm. Fitting was started at the top level with all the parameters of other levels kept fixed. Once the χ^2 minimization was achieved by the MINUIT program, the background and the contaminant peak parameters were fixed and the procedure was followed for the next lower level.

Table 1 Lifetime and B(E2) values of quadrupole bands in ^{140}Sm . Error bars on measured lifetimes include fitting error and error in side feeding intensities.

E_γ (keV)	I^π	T (ps)	B(E2) (e^2b^2)
994	16^+	$2.47^{+0.1}_{-0.1}$	$0.034^{+0.001}_{-0.001}$
1151	18^+	$1.32^{+0.07}_{-0.07}$	$0.031^{+0.002}_{-0.002}$
442	12^+	22	
619	12^+	11	
751b	14^+	1.7	

After obtaining χ^2 minimization for each level, a global fit was carried out, with the background and the contaminant peak parameters of all the levels kept fixed. However, it should be noted that quoted errors do not include systematic errors in stopping power values which may be as large as 20%. Fig. 2 displays χ^2 fit for 1151 and 994 keV γ -rays. B(E2) values are calculated using the following equation

$$(3.1) \quad B(E2) = \frac{0.0816 B_\gamma(E2)}{E_\gamma^5(E2) \tau [1 + \alpha_t(E2)]} (\text{eb})^2$$

Earlier lifetime measurement in ^{140}Sm has been carried out by M.A. Cardona et al.⁵ using RDM technique for 12^+ and 14^+ state and are listed in Table 1. The value quoted for lifetime and transition probability in Table 1 for 442 keV ($12^+ \rightarrow 10^+$), 619 keV ($12^+ \rightarrow 10^+$), 751 keV ($14^+ \rightarrow 12^+$) are taken from reference⁵.

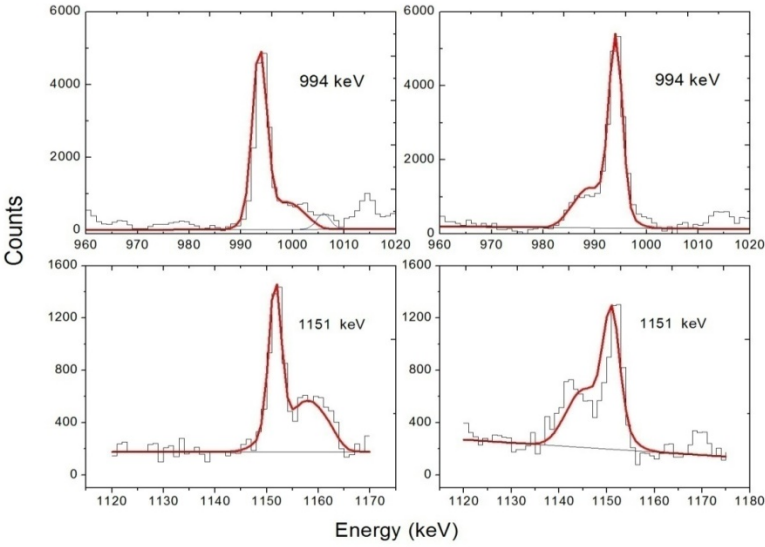


Figure 2: Results of χ^2 fits of the line shape analysis.

4. Conclusion

Lifetime and transition probability of a few states have been calculated in ^{140}Sm nucleus. The available information will be helpful in deciding deformation of above nuclei.

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