High Spin States in ^{41}Ca

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Introduction

Nuclei in the light mass region with A $\sim$ 30-40 often exhibit coexistence of single particle and collective excitations even near the shell closures. Evidence for multiparticle excitations across the $sd-fp$ shell gap leading to deformation, moderate or substantial, has been established in this region. Thus, the level structure of these nuclei is expected to exhibit interesting characteristics that may indicate the interplay of single particle and collective degrees of freedom. The ^{41}Ca ($Z=20, N=21$) nucleus, with a single valence neutron outside the doubly magic ^{40}Ca core appears to be one of the simplest systems for investigations of the aforementioned features [1, 2]. However, previous studies on the nucleus has indicated that the level structure of the nucleus is more complicated than is expected of a simple one particle configurations and the same has been ascribed to the core excitations. These studies, carried out more than three decades back and with modest experimental setups notwithstanding, the experimental data on the nucleus is still sparse and, at times, discrepant. In this context, the present work reports an investigation of the high spin level structure in the ^{41}Ca nucleus, populated through heavy-ion induced fusion-evaporation reaction and probed using high resolution γ-ray spectroscopy tools.

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Experimental Details and Data Analysis

Interestingly, the ^{41}Ca nucleus was populated in an experiment primarily carried out with the objective of spectroscopic studies in the $A \sim 30$ region using ^{18}O target and ^{16}O beam. The target frame was of aluminum (Al) and part of the beam, hitting the frame, produced ^{41}Ca in the reaction ^{27}Al(^{16}O, pn) at E_{lab} = 34 MeV, with sufficient statistics for the present study. The beam was provided by the 15 UD Pelletron at the Inter University Accelerator Centre (IUAC), New Delhi. The detection system used was the Indian National Gamma Array (INGA), then stationed at IUAC and consisting of 18 Compton suppressed Clover detectors distributed at angles $\theta = 32°$ (3), 57° (4), 90° (5), 123° (3) and 148° (3). The acquired data were analyzed for level structure information using standard procedures. Further, the lifetime of several levels were determined using the Doppler Shift Attenuation Method (DSAM) by analyzing the observed Doppler shapes / shifts with the LINESHAPE code [3].

Results and Calculations

The level scheme of ^{41}Ca, as obtained in the present study, is illustrated in Fig. 1. Around twelve new γ-ray transitions have been have been included in the level structure, following this work, and the level scheme has been extended to an excitation energy

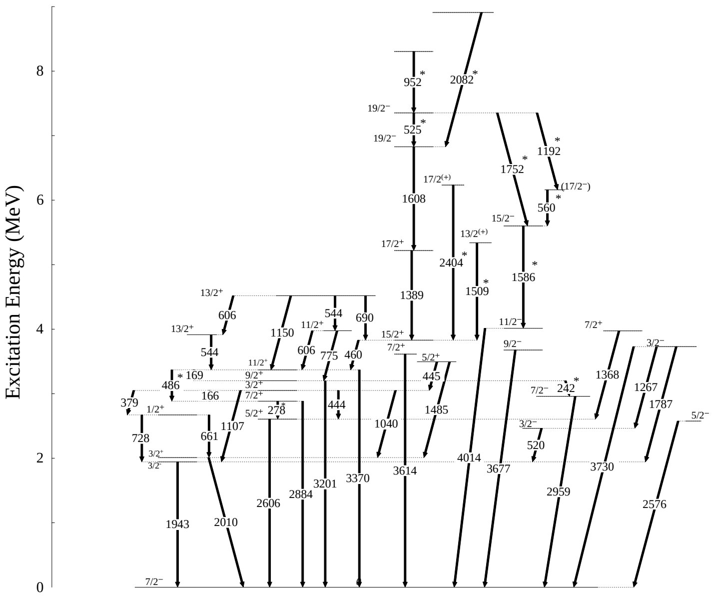

FIG. 1: Level scheme of the ^{41}Ca nucleus, as obtained from the present study. The γ-ray transitions identified for the first time in this work have been labelled with *.

$E_x \sim 9$ MeV and spin-parity $J^\pi = 19/2^-$. One of the results of particular interest is the $K^\pi = 3/2^-$ deformed band, identified by Lister *et al.* [2] was extended with three new levels, $J^\pi = 15/2^-, 17/2^-, 19/2^-$, in the current investigation. Lifetime analysis was carried out for several states in the ^{41}Ca nucleus, of which some were known previously while others were determined for the first time in the present work. The use of SRIM [4, 5] calculated stopping powers in lifetime analysis aided in restricting the uncertainties therefrom. Lifetimes could be determined for (i) the 3914 keV ($13/2^+$) level as 1650^{+90}_{-160} fs in agreement with the literature value of 2090^{+380}_{-380}, (ii) the 5219 keV ($17/2^+$) level as 47^{+23}_{-7} fs in compliance with the previously known upper limit of 40 fs and (iii) the 6827 keV ($19/2^-$) level as 1640^{+100}_{-100} fs in overlap with the reported upper limit of 2450 fs.

Large basis shell model calculations were carried out using the NuShellX [6] code. The model space for the calculations were $1d_{3/2}, 2s_{1/2}, 1f_{7/2}, 2p_{3/2}$ orbitals outside the ^{28}Si core and the interaction used was ZBM2 [7]. However, the limited success of the shell model in reproducing the experimental results indicated the dominance of multi-particle excitations and need for larger model space. The details of the results would be presented in the Symposium.

References

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