Spectroscopic study of ^{52}Cr

Arkadip Bera,[1] Abhijit Bisoi,[1,*] Rozina Rahaman,[1] Y. Sapkota,[2] A. Gupta,[3] Sangeeta Das,[1] Ananya Das,[4] Dibyadyuti Pramanik,[5] S. Rajbanshi,[6] A. Pal,[7, 8] Shefali Basak,[7, 8] Sansaptak Basu,[7, 8] S. S. Nayak,[7, 8] D. Kumar,[7, 8] S. Bhattacharya,[7, 8] T. Bhattacharjee,[7, 8] Saikat Chakraborty,[7, 8] G. Mukherjee,[7, 8] S. Bhattacharyya,[7, 8] A. Sharma[9], S. Kundu[9], Pankaj K. Giri,[9] R. Raut,[9] and S. S. Ghugre[9]

[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, Kolkata 700160.
[4]*Dream Institute of Technology, Samali, Kolkata- 700104, India*
[5]*Haldia Institute of Technology, Haldia- 721657, India*
[6]*Presidency University, Kolkata-700073, India*
[7]*Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata- 700064, India*
[8]*Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai- 400094, India*
[9]*UGC-DAE Consortium for Scientific Research, Kolkata Centre, Kolkata- 700098, India*
*Email: *abhijitbisoi@physics.iiests.ac.in*

Introduction

The spectroscopic study of $1f_{7/2}$ shell nuclei near N~28 is of significant interest because these nuclei serve as ideal candidates for description within the shell model framework. They exhibit a diverse range of nuclear phenomena, including collective behavior, band termination, and spherical-deformed shape coexistence. These phenomena have been effectively explained using advanced γ-ray spectroscopy techniques and have shown good agreement with shell model calculations.

Numerous studies have been conducted on ^{52}Cr using both heavy-ion and light-ion reactions. The most recent work on ^{52}Cr was reported by Rajesh Kumar *et. al*. [1]. In this study, the level scheme was extended up to 10 MeV, with spins reaching $J^{\pi}=(13^+)$. They also identified two bands with $K=0^+$ and $K=4^+$. The observed level scheme was compared with microscopic projected Hartree-Fock calculations, revealing a mixed configuration for the ground state band and a prolate configuration for the excited $K=4^+$ band. However, no lifetime measurement was carried out.

The primary objective of this study is therefore to investigate the level scheme of ^{52}Cr and interpret them microscopically using shell model calculations, as no such comprehensive study has been previously reported for this nucleus. Additionally, level lifetimes for several states are missing from the literature. In this study, level lifetimes were measured for the first time for certain states, while others with large uncertainties in reported values were remeasured.

Experimental Details

High-spin states of ^{52}Cr were populated via ^{51}V(^{4}He,*2np*)^{52}Cr fusion evaporation reaction with 45 MeV beam at Variable Energy Cyclotron Centre (VECC), Kolkata. A self-supported ~12 mg/cm^2 thick natural Vanadium target was used for the experiment. The de-excitation of γ-rays was detected using the Indian National Gamma Array (INGA) of 11 Compton-suppressed clovers and 1 LEPS. The coincidence events were recorded in list mode using a PIXIE-16 based digital data acquisition system [2]. The raw data was sorted using the BiNDAS package [3] and the data analysis was carried out using INGASORT [4]. Energy calibration was performed with some online gammas using the Autocal package [3]. The relative efficiency of the clover detectors was determined using radioactive sources ^{152}Eu and ^{66}Ga.

Results and Discussions

The excited states of ^{52}Cr were investigated through coincidence relationships and relative intensity measurements using a symmetric 90° vs 90° matrix, with careful consideration given to the angular distribution of dipole and quadrupole transitions. All existing levels were observed by putting a gate on the 1434 keV ground state transition. The partial level scheme is presented in Fig. 1. Directional correlation (DCO) and polarization (IPDCO) measurements were conducted using angle-dependent asymmetric matrices to assign or confirm the spin and parity of the levels. The spin and parity of 9440 and 10159 keV levels were assigned earlier tentatively [1]. We have confirmed their spin and parity as 12^+ and 13^+, respectively. Additionally, multipole mixing ratios (δ) for selected transitions of interest were calculated using the ANGCOR computer code [5].

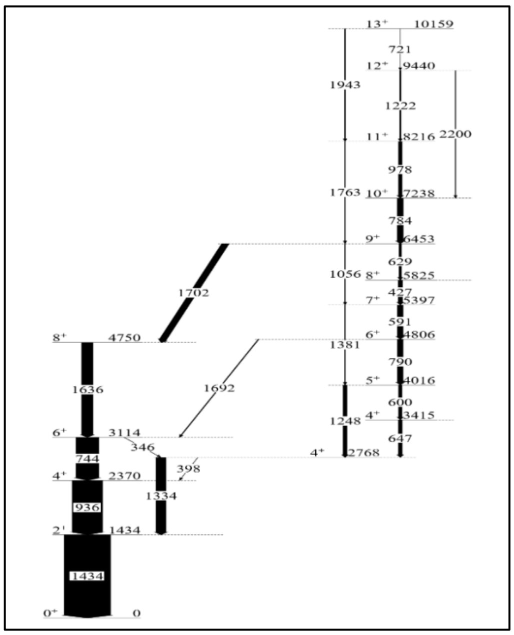

Fig. 1 Partial level scheme of ^{52}Cr

Doppler-shifted lineshapes were observed for several transitions. The lifetimes of six levels were measured, with the 9440 keV and 10159 keV levels being measured for the first time. The lifetimes of four other levels (4750, 6453, 7238, and 8216 keV) have large uncertainties [6]. We have therefore remeasured their lifetimes. We have used a modified version of the LINESHAPE computer code [7] to extract the lifetimes. The fitted lineshape spectra from this analysis are shown in Fig. 2. The measured lifetimes, on the order of picoseconds, are consistent with previously reported values but with less uncertainties. Large basis shell model calculation was performed using the NuShellX code [8] with the effective interaction KB3GPN [9], yielding results that closely match the experimentally observed level energies. A more detailed theoretical study on the band structure of ^{52}Cr is yet to be done.

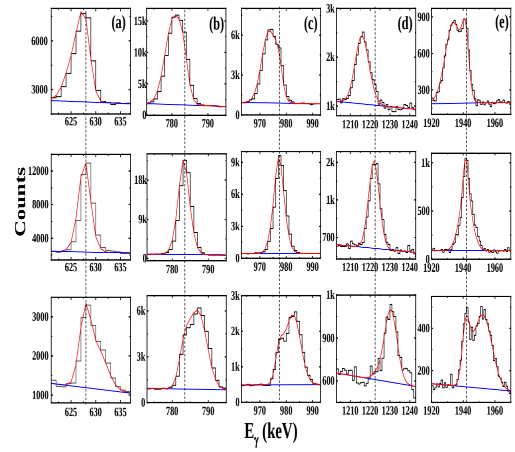

Fig. 2 Experimental (black) and simulated (red) line-shape spectra are shown for the (a) 629, (b)784, (c) 978, (d) 1222, and (e) 1943 keV transitions for the angles 125º (top), 90º (middle), and 40º (bottom).

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