Single-particle and collective structure in ^{51}Cr

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Introduction

Nuclei with Z and N between 20 and 28 provide an unique opportunity to study the interplay of single-particle and collective structure within the same nucleus. This is possible because, the $A-40$ nucleons occupying the $f_{7/2}$ shell outside a ^{40}Ca core is low enough to allow a full shell model description and at the same time high enough to develop collective behaviour with all its consequences.

The level scheme of the ^{51}Cr nucleus, with four proton particles and one neutron hole in the $f_{7/2}$-shell, is indicative of single particle nature. However, a strongly deformed $K^{\pi}=1/2^{-}$ band was also suggested in this nucleus [1]. Gamma transitions from the excited levels of this band to the yrast single-particle states were found to be highly hindered. This strongly deformed band structure was explained as a consequence of the occupancy of 1/2[321] orbital which goes down steeply with increasing deformation, thus favouring a large stable deformation [1]. The experimental data on the excited states of ^{51}Cr are rather sparse. The latest work on this nucleus was reported by Cameron *et al.* where ^{40}Ca(^{14}N,3p) and ^{27}Al(^{27}Al,2pn) reactions were used with a moderate array of three to five Ge detectors and a NaI multiplicity filter [2]. In that work, apart from the $f_{7/2}$ band-terminating state at $J^{\pi}=23/2^{-}$ with E_x=5.711 MeV, a further transition from the pf band were also observed.

Here in this paper, we report new observations on the high-spin level structure of ^{51}Cr.

Experimental details

High spin states in ^{51}Cr were populated using the ^{27}Al(^{28}Si, 3pn)^{51}Cr reaction at the BARC-TIFR Pelletron facility. The ^{28}Si beam impinging on the target was of energy 100 MeV. A self-supporting target as well as a backed target were used for a complete measurement of the experimental observables. In the measurement using self-supporting target, two Al foils of thicknesses 500- and 510 μg/cm^2 with the former facing the beam were stacked one after the other. An equidistant air gap between the foils was created by placing a thin metallic frame with a circular aperture of diameter similar to the target. The backed-target consisted of a $\sim$750 μg/cm^2 thick Al foil with a 14.8 mg/cm^2-thick layer of Au backing. The de-exciting γ rays were detected by the Indian National Gamma Array (INGA), then consisting of twenty Compton-suppressed clover Ge detectors.

Results and discussions

The preliminary level scheme of ^{51}Cr as obtained in the present study is shown in Fig. 1. Apart from the observation of almost all the previously reported transitions, several other new transitions were observed in the analysis of the triple-γ coincidence data.

The $K^{\pi} = 1/2^{-}$ strongly deformed band which was earlier reported from α induced reaction has been observed in the present data. Efforts are being made through lifetime and B(E2) measurements to quantify and have a clear idea of the associated deformation.

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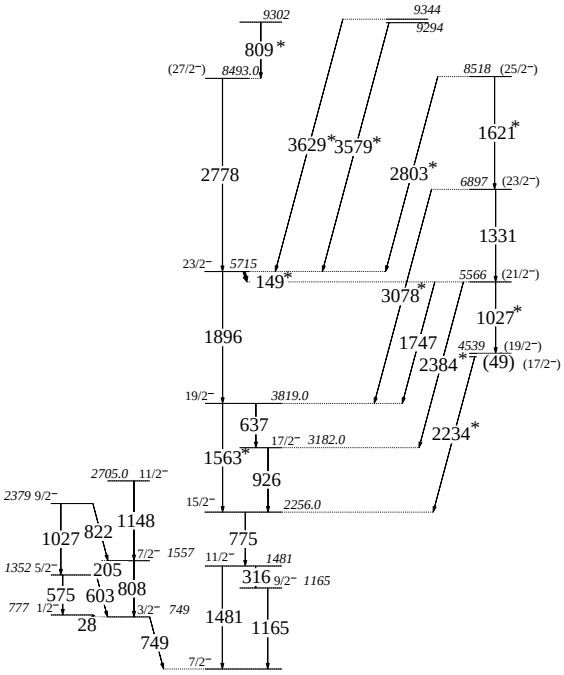

FIG. 1: The partial level scheme of ^{51}Cr as obtained in the present study. The transitions marked with "∗" are newly observed.

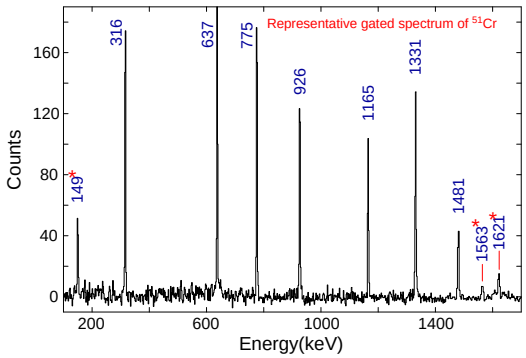

FIG. 2: Representative gated spectrum of ^{51}Cr with double-coincidence gates on 1747 keV transition and one of the transitions from the list L: 1165, 1481, 316, 775, 926, 637, 1563 keV. The newly observed transitions are marked with "∗".

The single particle states were observed up to an excitation energy of ∼9.3 MeV. It is to be noted that the lifetimes of the states beyond I=15/2$^-$ (E$_x$=2256 keV) are not clearly known. The backed-target data recorded in several angles of the INGA array gives us an opportunity to extract the lifetimes of the single particle states up to band-termination and even beyond that. This will certainly clarify the dip in B(E2) value at spin I=19/2$^-$ obtained in theoretical shell-model calculation using various effective interaction. A ΔJ=1 sequence of γ-rays is being newly proposed in the present study. This short sequence of γ-rays has been observed up to an excitation energy of ∼8.5 MeV. The 21/2$^-$ and 23/2$^-$ levels in this sequence were reported earlier. Several unambiguous high-energy (of the order of 2 MeV and above) inter-band transitions affirm the placement of this band and the spin-parity of the levels. It is to be noted that in the previous work by Cameron *et al.*, it was mentioned that the fast-feeding of the yrast 19/2$^-$ and 17/2$^-$ states comes through unobserved side-feeds [2]. The newly observed inter-band transitions which feed into these levels might be the candidate transitions for such side-feeds. Large scale shell model calculation with ^{40}Ca core and a valence space in the full fp-shell (and even beyond that) will be shortly undertaken to understand the underlying configuration of the single particle states. The calculated reduced transition rates and quadrupole moments will be compared with the experimental values. The analysis is in progress, and the results will be presented in detail during the symposium.

Acknowledgments

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References

[1] Jirohta Kasagi and Hajime Ohnuma, J. Phys. Soc. Japan **45**, 1099 (1978).
[2] J. A. Cameron *et al.*, Phys. Rev. C **44**, 2358 (1991).