Spectroscopic study of ^{96}Mo nucleus

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Introduction

The shape of the even-A Mo isotopes shows a transition from a spherical vibrator at ^{92}Mo to a deformed rotational nucleus at ^{104}Mo. The ^{92}Mo having $N = 50$ is located at neutron shell closure, whereas ^{104}Mo is driven by the enhanced proton-neutron residual interaction leading to large deformation at $N = 60$. Situated in between, the nucleus of interest, ^{96}Mo lies in a transitional region between $N=$ 50 and 60 and is pivotal for understanding shape transitions effects in this mass region. In recent times, there has been considerable efforts to explain the shape coexistence in ^{98}Mo and ^{100}Mo, band crossing in ^{100}Mo [1], γ softness in ^{102}Mo, and triaxiality in ^{104,106,108}Mo [2]. The 2_1^+ state is observed at 192.2 keV in ^{104}Mo, and E(4_1^+)/E(2_1^+) was measured to be 2.9, that represents a near rotor value. Further, there is an important development regarding the mixed-symmetry states at low energies in ^{94}Mo and this is characterized by collective states that are not fully symmetric with respect to the (np) degree of freedom [3, 4]. Even in ^{96}Mo, the yrast band was found to be based on vibrator. However, observation of 2^+_{ms} at 2.095 MeV has also endorsed the existence of mixed symmetry states at higher excitation energy [5]. $M1$ transitions discussed in the mixed-symmetry section suggest that ^{96}Mo is closer to O(6) symmetry than U(5). However, the vibrational picture may remain partially intact through the one- and two-phonon structures. Motivation of the present work is to probe into shape coexistence in ^{96}Mo.

Experimental Details

Excited states of ^{96}Mo were populated through the process of fusion-evaporation reaction ^{94}Zr(^{4}He, 2n)^{96}Mo at a beam energy of 30 MeV. The thickness of the target was 6mg/cm^2 with a backing of Myler foil having a thickness of 200 micron. Alpha beam was administered from K-130 cyclotron at VECC, Kolkata, India. The de-excited γ rays were detected by the VECC-INGA comprising of eleven Compton-suppressed HPGe(high purity germanium) clover detectors, one LEPS

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(Low Energy Photon Spectrometer) detector and six CsI detectors.

Results and Discussions

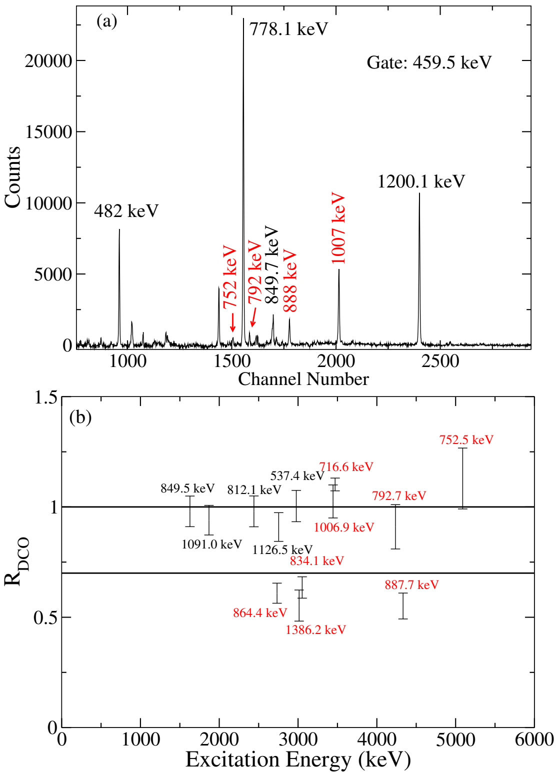

FIG. 1: (a) The γ-γ coincidence spectrum gated on 459.5-keV transition. Peaks shown in the red color are some of the newly placed strong transitions in ^{96}Mo. Transitions shown in black color were already reported in earlier literatures. Here channel number is double the energy. Whereas (b) represents the R_{DCO} values of the transitions as a function of excitation energy these R_{DCO} values have been obtained in quadrupole gates, gammas shown in the red colour are the new ones, gammas shown in the black colour are already reported.

Data obtained from the experiment has been sorted using BiNDAS [6] to construct γ-γ matrices and γ-γ-γ cube. Analysis was done using RADWARE package [7]. New γ transitions were placed on the basis of coincidence relation as well as intensity balance and the low spin part of the level scheme was extended up to $\approx$ 5 MeV, 10 $\hbar$. A representative spectrum is shown in Fig.1(a). Spin of the already known levels as well as the newly placed states are assigned using the method of directional correlation from the oriented states (DCO) ratio, which is defined as:

$$R_{DCO} = \frac{I\gamma_1 \; at \; 125^\circ, \; gated \;\; by \; \gamma_2 \; at \; 90^\circ}{I\gamma_1 \; at \; 90^\circ, \; gated \;\; by \; \gamma_2 \; at \; 125^\circ}$$

The value of R_{DCO} for a pure dipole (quadrupole) transition gated by a stretched quadrupole (dipole) transition is 0.7 (1.6). The DCO ratios of the transitions in ^{96}Mo have mostly been determined using quadrupole gates owing to their strong intensity. The R_{DCO} values are plotted as a function of excitation energy in the Fig.1(b). Polarization measurements of the observed transitions and further analysis to find out the nature of the newly found γ-rays are in progress.

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References

[1] P. H. Regan, *et al.*, Phys. Rev. C **68**, 044313 (2003).
[2] J. Skalski, *et al.*, Nucl. Phys. A **617**,282 (1997).
[3] N. Pietralla, *et al.*, Phys. Rev. Lett. **84**, 3775 (2000).
[4] C. Fransen, *et al.*, Phys. Lett. B **508**, 219 (2001), Phys. Rev. C **67**, 024307 (2003).
[5] S. R. Lesher, *et al.*, Phys. Rev. C **75**, 034318 (2007)
[6] S. S. Nayak, G. Mukherjee, IEEE transactions on nuclear science, VOL. **70**, NO. 12 , December 2023
[7] D. C. Radford, Nucl. Instrum. Methods Phys. Res. A **361**, 297 (1995).