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High spin rotational bands in ^{65}Zn

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Abstract. The nucleus $^{65}_{30}$Zn was studied using the ^{52}Cr(^{16}O, $2pn$)^{65}Zn reaction at a beam energy of 65 MeV. The level scheme is extended up to an excitation energy of 10.57 MeV for spin-parity (41/2$\hbar$) with several newly observed transitions placed in it.

Keywords. Nuclear reaction: ^{52}Cr(^{16}O, $2pn$) $E = 65$ MeV; measured E_γ, I_γ; γ–γ-charged particle coincidence; ^{65}Zn deduced high spin levels, J^π.

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1. Introduction

We present here some preliminary results from our studies in the $A \sim 60$ region in which we have observed an yrast band structure in ^{65}Zn extending to spin (41/2$\hbar$). This nucleus lies in a region of nuclei where the shape is changing rapidly as a function of neutron and proton number. The proximity of the $N = 38$ prolate and the $N = Z = 34, 36$ oblate shell gaps implies that nuclei may exhibit different shapes at different excitation energies. In all the nuclei in this region [1–4], the positive parity structure based on the $g_{9/2}$ orbital forms the yrast line at high spins and, given the well-known understanding about the competition between shapes for this parity, it is of interest to follow the evolution of this structure to higher rotational frequencies.

The low-spin structure of the odd-A nucleus ^{65}Zn has been studied previously using both alpha induced reactions [5,6] and various transfer reactions [7–9]. No heavy-ion induced reaction has been attempted to explore the high-spin states for this nucleus. The most recent attempt to describe the structure of its low-lying levels [6] concluded that the first positive parity level, the J^π= 9/2$^+\hbar$ state at 1.065 MeV, can be interpreted as more than 90% of a $g_{9/2}$ quasineutron coupled to a zero phonon excitation. Moreover, with an alpha projectile they could only populate up to the state at 5.769 MeV with no spin-parity assignment. The lifetime measurements of the 17/2$^+_1\hbar$, 17/2$^+_2\hbar$, and 21/2$^+\hbar$ states at 3226, 3784, and 4934 keV energies respectively, indicated an enhancement in the B(E2) values of the 1173, 1731, and 1708 keV transitions and hence, suggested the possibility of onset of deformation at high-spins. In order to investigate the possible shape changes in this nucleus, we have studied it to higher spin, which has established the predicted existence of collective bands for the first time.

2. Experimental procedure

This nucleus ^{65}Zn was studied at the Nuclear Science Centre – 15UD pelletron facility using the ^{52}Cr(^{16}O, $2pn$)^{65}Zn reaction at a beam energy of 65 MeV. The beam impinged on a natural (85% abundance) target of thickness 1 mg/cm^2 backed by a 7 mg/cm^2 thick gold foil. Prompt γ-rays were collected using the gamma detector array (GDA) of twelve Compton suppressed germanium detectors (four at 45°, four at 99° and four at 153°) located at the target position, in coincidence with the evaporated charged particles detected with the 4π charged particle detector array (CPDA) [10]. The total photopeak efficiency of the array was measured to be 25% relative to a standard $3''\phi \times 3''$ NaI detector. The CPDA, consisting of 14 phoswich $\Delta E - E$ detectors, selected the evaporation channels of the charged particles. The $2pn$ evaporation channel leading to ^{65}Zn represented $\sim$ 22% of the total fusion cross section.

3. Data analyses and results

A total of 9.4×10^7 γ–γ-charged particle coincidence events were collected for an offline analysis, from which γ–γ matrices were created by applying different gating conditions set on the number of detected protons and/or alpha particles [11,12]. The γ–γ coincidence relationship for ^{65}Zn were derived from a $4k \times 4k$ matrix gated on $2p$ reaction channel. Coincidence, intensity balance, and summed energy relations were inspected to deduce the high spin excitation scheme. The γ-ray energies and intensities presented in the level scheme are based on the previously mentioned 2 proton gated γ–γ matrix. But for weak transitions and/or doublet structures, γ-gated spectra obtained from total γ–γ matrix were considered. Spin and parity assignments were made on the basis of a DCO-type analysis [13] and from the known 5/2$^-\hbar$ spin-parity value of the ground state. A separate γ–γ coincidence matrix was constructed with events detected in detectors at 153° (θ_1) versus those at 99° (θ_2) detectors, from which the DCO ratios were extracted.

The decay scheme of ^{65}Zn derived from this work is shown in figure 1. This work confirms almost all the states reported in earlier experiment [6], which had used α induced reactions to populate the nucleus. In our study, a total of 21 previously unreported states and 46 new γ transitions (marked by an asterisk in figure 1) have been observed and properly placed in the level scheme, thereby the level scheme is extended up to an excitation energy of 10.574 MeV and spin-parity of (41/2$^+\hbar$). This data establishes transitions at 1074, 1155, 1227, and 1349 keV which form the upper part of the $g_{9/2}$ band structure. The γ-ray at 1072 keV was observed previously [6] but the doublet partner 1074 keV was not resolved due to poor resolution of the detectors used. The measured DCO ratios for the 835, 988, 1074, 1155, 1173, 1227, 1349 and 1708 keV transitions are consistent with stretched E2 transitions. Thus the yrast band built on 9/2$^+\hbar$ state at 1065 keV has been observed to extend up to $J^\pi = (41/2^+\hbar)$ state at 10.574 MeV. States up to 5.769 MeV were known previously but not considered as a part of $g_{9/2}$ band. Another +ve parity band of weak E2 transitions is found to build up on the previously known 13/2$^+_2\hbar$ state at 2.923 MeV. The 1155 keV, 17/2$^+\hbar$ to 13/2$^+\hbar$ transition was already known. This band is extended up to 8.327 MeV, (29/2$^+\hbar$) with the observation of 1262, 1413 and 1574 keV E2 transitions in coincidence with 1155 keV transition. We are trying to understand the observed yrast band

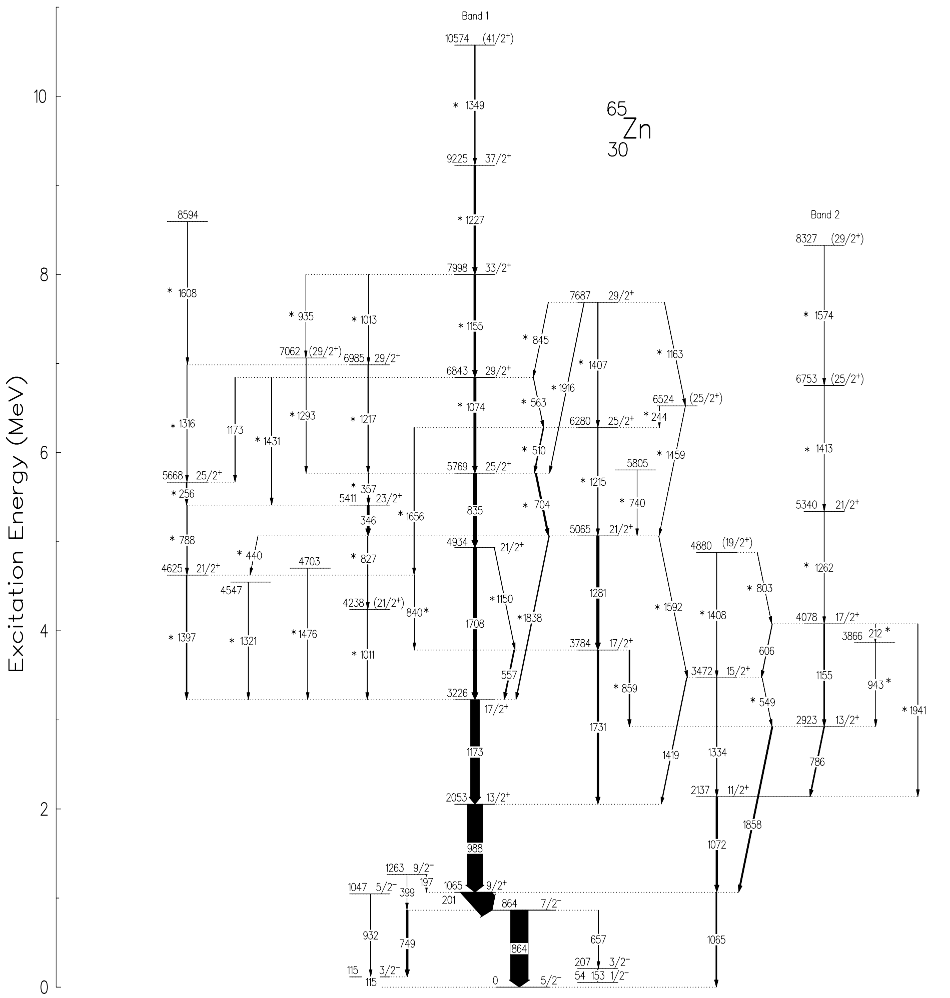

Figure 1. Proposed level scheme for ^{65}Zn. Transition energies are given to the nearest keV, and the width of the arrows corresponds to the relative γ-ray intensities. Newly observed transitions are marked by asterisks (*).

structure of ^{65}Zn in the framework of cranking model with the Woods–Saxon potential, the results of which will be published shortly.

4. Conclusion

In summary, the high spin states of ^{65}Zn have been studied with the GDA+CPDA configuration, identifying previously unobserved states up to an excitation energy of 10.57 MeV.

This nucleus was populated following the fusion reaction ^{52}Cr + ^{16}O. From the observed decays of states and DCO ratios, it was possible to assign spins and parities of these states observed. We have also observed an yrast band structure in this nucleus for the first time.

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References

[1] C E Svensson *et al*, *Phys. Rev. Lett.* **79**, 1233 (1997)
[2] M Devlin *et al*, *Phys. Rev. Lett.* **82**, 5217 (1999)
[3] T F Lang, D M Moltz, J E Reiff, J C Batchelder, J Carney, J D Robertson and C W Beausang, *Phys. Rev.* **C42**, R1175 (1990)
[4] A M Bruce *et al*, *Phys. Rev.* **C62**, 027303 (2000).
[5] A Nilsson and Z P Sawa, *Phys. Scr.* **9**, 83 (1974)
[6] P Banerjee, B Sethi, M B Chatterjee and R Goswami, *Phys. Rev.* **C50**, 1813 (1994)
[7] A Kogan, P R G Lornie, G D Jones, M R Nixon, H G Price, R Wadsworth and P J Twin, *J. Phys. (London)* **G4**, 755 (1978)
[8] A Charvet, J Sau, R Duffait and R Chery, *Phys. Rev.* **C15**, 1679 (1977)
[9] G F Neal, Z P Sawa and P R Chagnon, *Nucl. Phys.* **A295**, 351 (1978)
[10] S Muralithar *et al*, *Proc. DAE Symp. on Nucl. Phys. (India)*, **B41**, 404 (1998)
[11] B Mukherjee, S Muralithar, R P Singh, R Kumar, K Rani, S C Pancholi and R K Bhowmik, *Pramana – J. Phys.* **55**, L471 (2000)
[12] B Mukherjee, S Muralithar, R P Singh, R Kumar, K Rani and R K Bhowmik, *Phys. Rev.* **C63**, 052105 (2001)
[13] A Kramer-Flecken, T Morek, R M Lieder, W Gart, G Hebbinghaus, H M Jager and W Urban, *Nucl. Instrum. Methods* **A275**, 333 (1989)