Rigid Rotor Like Dipole Band Structure in ^{29}Al

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Introduction

Among the *sd*-shell nuclei, the odd-mass ^{29}Al is found to be one of the case where the spectroscopic information related to its level structure is still scarce. All the previous experimental investigations on ^{29}Al were carried out using β-decay, transfer reactions and fusion-evaporation reactions with alpha beam. All these studies could establish the level structure of ^{29}Al upto an excitation regime of $\sim$ 3 MeV with firm spin-parity assignments of the underlying levels. We are reporting here the new findings related to the level structure of ^{29}Al that has been obtained for the first time from an investigation using heavy-ion fusion evaporation reaction. The level scheme could be established up to $E_x \sim 9$ MeV with $J^\pi = (15/2^+)$. This is so far the highest observed spin among all the odd-mass aluminium isotopes.

Experimental Details

The experiment was performed with the ^{18}O(^{13}C, 1p1n)^{29}Al reaction, using a 30-MeV ^{13}C beam provided by the BARC-TIFR Pelletron Linac facility at Mumbai, India. The molecular target in the form of Ta_2O_5 was prepared by heating a thick Ta-foil (of 50 mg/cm^2 thickness) in an atmosphere of enriched ^{18}O. The de-exciting γ-rays were detected using INGA (**I**ndian **N**ational **G**amma **A**rray). During the time of the experiment, the array was comprised of fifteen Compton suppressed high-resolution Clover detectors. The population statistics of the residual nuclei in the concerned experiment suggest that the nucleus ^{29}Al appears to be in the third position followed by ^{29}Si and ^{26}Mg. The new findings for ^{29}Si and ^{26}Mg obtained from this experiment have already been published elsewhere [1].

Experimental Results and Discussion

A representative $\gamma\gamma$ coincidence spectrum for ^{29}Al has been depicted in Fig. 1. A sequence of levels connected by ΔJ = 1 transitions has newly been observed in ^{29}Al. The variation of excitation energies of the concerned levels as a function of J(J+1) value has been presented in Fig. 2. The plot appears to be almost linear in nature (except a kink at the (11/2$^+$) level). This behavior is suggestive of a rotational like band character of the associated levels. The spins of the levels have been assigned from the results based on angular-asymmetry ratios. The moment of inertia values obtained from the standard rigid-rotor model and the corresponding experimental values are shown in Table I. The table indicates that the dipole band maintains the rigid rotor behavior upto the highest observed spins and excitations. The lifetimes of the levels

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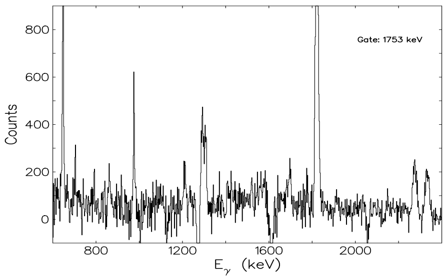

FIG. 1: A representative $\gamma\gamma$ coincidence spectrum with the gate set on the 1753($(7/2^+) \rightarrow (5/2^+)$)-keV ground state feeding transition. All the unmarked peaks with better statistics belong to ^{29}Al.

of the band have been obtained by using the DSAM technique with modified algorithm [2]. The newly obtained lifetime values have been used to compute the experimental $B(M1)$ values for the transitions of the band. Except for the 1753-($7/2^+ \rightarrow 5/2^+$)-keV ground state feeding transition (for which the associated experimental δ value is +0.18(2)), the δ values for the other transitions of the band are not known. Hence, the $B(M1)$ values for those transitions have been calculated without considering the δ-values. Detailed shell model calculations have been carried out using the shell-model code NuShellX @ MSU [3]. The calculations were initially performed using both the *sdpfmw* (the associated model space: *sdpf*) and the *usda* (the associated model space: *sd*) interactions. The two types of calculations have been named as: SM1 and SM2. The comparison between the experimental and theoretical level energies is found to be slightly better in SM2 calculations. Hence, the shell model results with SM2 calculations have only been presented here. Fig. 3 shows the variation of $B(M1)$ values for different transitions of the band under consideration. It appears that the comparison between $B(M1)_{expt}$ and $B(M1)_{SM2}$ is reasonable. The figure indicates the gradual fall of $B(M1)$ values as a function of spin and excitation.

TABLE I: Comparison of the moment of inertia values ($2\Im/\hbar^2$) in the unit of MeV^{-1}.

Rigid-rotor	Experimental$_I$ [a]	Experimental$_{II}$ [b]
8.5	4.6	9.4

[a] Considering the region between ($5/2^+$) to ($11/2^+$).

[b] Considering the region between ($11/2^+$) to ($15/2^+$).

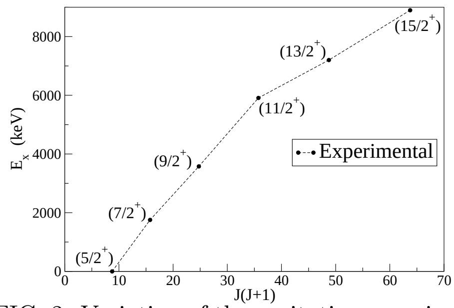

FIG. 2: Variation of the excitation energies of the levels of the newly observed dipole band in ^{29}Al as a function of J(J+1) values. The dotted line through the experimental data points has been drawn to guide the eye.

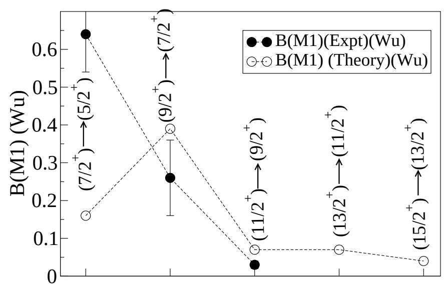

FIG. 3: Comparison between experimental and theoretical $B(M1)$ values for the transitions belong to the dipole band.

Acknowledgments

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