Study of Ground-state configuration of neutron-rich ^{35}Al

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Introduction: In 1979 Simons et al. [1] discovered neutron rich ^{35}Al by fragmentation of ^{40}Ar on carbon target. Four decades later, except some theoretical calculations, experimental information regarding ground state configuration of ^{35}Al are scarce . The ground state information of a nucleus gives direct insight into the nuclear wave function. ^{35}Al (with Z = 13 and N = 22) is lying in between the shell closures, N = 20 and 28 where many nuclei show anomalous behavior in comparison with standard shell model. Exclusive Coulomb breakup is a direct probe for studying the ground state configuration of loosely bound nuclei [3]. During October 2010, an experiment (s306) was performed to explore the properties of nuclei in and around N~20 "*Island of Inversion*" through electromagnetic excitation. The exclusive setup for kinematic ally complete measurement, the FRS-LAND setup at GSI, Darmstadt was used for this purpose. Here we shall report the ground state configuration of ^{35}Al via electromagnetic excitation.

Experiment and method of analysis:

Short-lived radioactive nuclei were produced by the fragmentation of pulsed ^{40}Ar beam (at 531 MeV/u) on Be (8 gm/cm^2) production target at fragment separator (FRS). Secondary beam from FRS, containing ^{35}Al were allowed to fall on various targets [Pb for electromagnetic excitation, Carbon for nuclear excitation and without target for reactions induced by detector materials] at Cave C where kinematic ally complete measurement were performed using the exclusive FRS-LAND set-up. Data analysis has been performed using CERN-ROOT platform and *land02* framework with modification from SINP group. The incoming beam was identified uniquely by energy loss and ToF measurements before the reaction target along with the known magnetic rigidities of FRS[4,5]. Neutrons and γ-rays from the de-exciting projectile or projectile like fragments were detected by the LAND and the 4π-Crystal Ball spectrometer, respectively. Reaction fragments were tracked via the Silicon Strip Trackers and GFI detectors placed before and after the magnetic spectrometer (ALADIN), respectively. Finally, mass of the outgoing fragments were identified by reconstructing the magnetic rigidities inside ALADIN and velocity measurements of the reaction fragments. All the γ-rays detected by the 4-π crystal ball detector in the laboratory frame were subjected to Doppler correction resulting in the reconstructed energy in the rest frame. ^{34}Al reaction fragments were obtained after Coulomb break-up of ^{35}Al. Fig. 1 shows the γ-sum spectrum of ^{34}Al obtained in coincidence of the fragment with the one neutron. By measuring the four-momenta of all the decay products, the excitation energy E^* of the nucleus prior to decay was reconstructed on an event-by-event basis by analysing the invariant mass. The resulting data was analyzed on the basis of direct breakup model. The differential Coulomb dissociation cross section $d\sigma/dE^*$ for dipole excitations decomposes into an incoherent sum of components $d\sigma(I^{\pi}_{c})/dE^*$ corresponding to different core states with spin and parity, I^{π}, populated after one-neutron removal and can be expressed as[3].

$$\frac{d\sigma}{dE^*} = \frac{16\pi^3}{9\hbar c} N_{E1}(E^*) \sum_j C^2 S(I^{\pi}_{c}, nlj) \times \sum_m \left| \langle q | (Ze/A) r Y^{l}_{m} | \psi_{nlj}(r) \rangle \right|^2$$

Where, r represents the relative distance between the core and the valance neutron; $(Ze/A)rY^{l}_{m}$ stands for the E1 operator corresponding to nucleus $^{A}X_{Z}$ and the summation runs over all possible contributing dipole transitions. Each of the contributing components is weighted by an appropriate spectroscopic factor $C^2S(I^{\pi}_{c};nlj)$. $N_{E1}(E^*)$ is the number of equivalent dipole photons of the target Coulomb field at an excitation energy E^*,which can be computed in a semi-classical approximation. Here, the final states $|q>$ of the valance neutron have been approximated by a plane wave and the single particle initial states $|\psi_{n,l,j}>$ have been derived from a Wood-Saxon potential.

Results:

The ground state spin and parity of ^{35}Al is not known and from systematic, it is considered to be $5/2^+$. For a β-stable nuclei with neutron number, N=22 the valance neutron should occupy the $1f_{7/2}$ orbital. In case of ^{35}Al, if the valance neutron occupies pure $1f_{7/2}$ orbital then calculated Coulomb dissociation cross-section is 4 mb. But enhanced total CD cross-section of 77±10 mb reject that possibility. Comparison of experimental differential CD cross-section with direct breakup model calculation clearly suggest that neutron(s) is occupying $p_{3/2}$ orbital coupled with ^{34}Al(g.s:4^-). Thus occupation of valance neutron in $p_{3/2}$ orbital is possible when N= 28 shell gap merging with each other, as predicted by *sdpf-M* shell model calculation[3]. Monte-Carlo shell model calculation by Otsuka et al. [6] has predicted the lowering of $2p_{3/2}$ orbital for aluminum isotopes around N~20 shell gap.

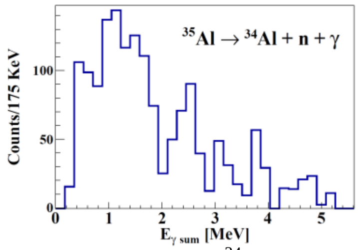

Fig. 1 γ-sum spectra of ^{34}Al obtained after Coulomb breakup of ^{35}Al in lead target.

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