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Redefining the edge of the island of inversion for Na nuclei

The magic numbers of the nuclei, proposed by Mayer and Jensen are a benchmark of nuclear structure. The underlying shell gap is a characteristic of the mean nuclear field which takes into account of many ingredients of the nucleon-nucleon interactions. Recently, it has been noted that these magic numbers are no longer valid in the exotic nuclei which are far away from the β-stable line and close to the drip line. The modification in the shell gaps through effects such as the tensor component of the N-N force become pronounced with large neutron–proton asymmetries in the exotic nuclei. These lead to the disappearance of established magic numbers and the appearance of new ones. Large deformation was reported in nuclei for N˜20, e.g. 31Na, 32Mg etc. The large deformation in those nuclei was explained by considering the intruder effects which suggests a clear vanishing of the shell gap between sd and pf shell around N = 20. The N = 20 isotones for Z =10−12 are considered to belong to the "island of inversion" where intruder configurations dominate the ground state wave function. Though it is established that the valence neutron(s) in the ground state of the neutron-rich Na, Mg, Ne isotopes at N=20, occupies pf intruder orbitals, but this is not well established for the neighboring nuclei. Recently nuclei with N˜20 have been studied and valence nucleon occupancy in the pf orbital is reported by our group. An experimental program GSI-S306 was initiated to explore ground state configurations of neutron-rich nuclei around N=20 through Coulomb breakup of secondary beams at intermediate energy (400−500) MeV/nucleon. Coulomb breakup is a direct method to probe the quantum numbers of the valence nucleons of loosely bound nuclei [1]. The invariant mass spectra of 29,30Na have been obtained through measurement of the four-momenta of all decay products after Coulomb excitation of those nuclei on a 208Pb target at energies of 400–430 MeV/nucleon [2, 3]. The major part of one neutron removal, CD cross-sections of those nuclei populate the core, in its ground state. A comparison with the direct breakup model, suggests the predominant occupation of the valence neutron in the ground state of 29Na (3/2+) and 30Na (2+) is the d-orbital with a small contribution from the s-orbital, which are coupled with the ground state of the core. The ground state spin and parity of these nuclei obtained from this experiment are in agreement with earlier reported values. The spectroscopic factors for the valence neutron occupying the s and d orbitals for these nuclei in the ground state have been extracted and reported for the first time. Interestingly it has been found that the spectroscopic factor for the valence neutron in the d-orbital for 29Na is in close agreement with USD-B calculation; however it is less by 1/3 for 30Na. Hence in contrary to the previous works, we can conclude that 29Na is probably not a member of the island of inversion and we propose 30Na as the new boundary [4]. A comparison of our experimental findings with shell model calculation using the MCSM suggests a lower limit of around 4.3 MeV of the sd–pf shell gap in 30Na.

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Primary author: Dr MD. ANISUR RAHAMAN1,2 AND USHASI DATTA2 FOR GSI-S306 (1Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata-700064 2Jalpaiguri Government Engineering College, Jalpaiguri-735102)

Presenter: Dr MD. ANISUR RAHAMAN1,2 AND USHASI DATTA2 FOR GSI-S306 (1Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata-700064 2Jalpaiguri Government Engineering College, Jalpaiguri-735102)