New boundary of "island of inversion" for Na isotope

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Introduction

Contrary to the present experimental information regarding the boundary of "island of inversion" for Na isotope available in literature, [1, 2] our recent experimental [4] findings reports ^{30}Na as the new candidate for it instead of ^{29}Na. Coulomb breakup measurement with coincidence γ-ray measurement [3,5] is known as the direct probe to study the ground state configuration of loosely bound nuclei since the tail part of the wave function of the outgoing neutron is highly sensitive to the virtual photons. The invariant mass spectra of ^{29,30}Na nuclei have been obtained through measurement of the four-momentum of all decay products after Coulomb excitation on a ^{208}*Pb* target at energies of 400-430 AMeV using FRS-ALADIN-LAND setup at GSI, Darmstadt. Due to the large neutron-proton asymmetry in the exotic nuclei far away from stability, the shell gaps are modified through the effects of special components of the nucleonic interaction, such as tensor force (here especially the strong attractive monopole part), spin orbit interaction and the three-body force etc. In our experimental finding we have suggested a lower limit of the shell gap from the estimate of the excited state contribution to the core.

Experiment

A beam containing ^{29,30}Na isotopes along with others were populated by fragmentation of the ^{40}Ar beam with energy 540 AMeV from the SIS synchrotron at GSI, Darmstadt. The incoming projectiles were identified [Fig 1] event-by-event by measuring the magnetic rigidity, time of flight and relative energy loss of the exotic nuclei. The secondary beam was separated at FRS and transported to the experimental site, a neighboring cave C where the complete kinematic measurements were performed using secondary targets of ^{208}Pb (2 gm/cm^2), ^{12}C (0.935gm/cm2) and empty target. The purpose of using empty and Carbon target was to obtain the background and nuclear contribution for accurate measurement of the Coulomb dissociation cross-section using ^{208}Pb target. For the tracking of the incoming beam as well as the reaction fragments after the secondary target we have used double sided SST detector, GFI, TFW and LAND detector [4]. A crystal ball detector consists of 162 NaI detectors covering almost 4Π solid angle were used for detecting the γ-rays from the excited core of the projectile after the Coulomb breakup.

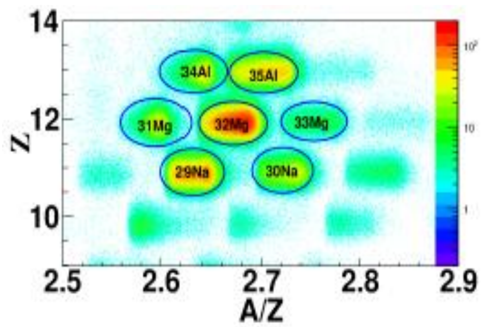

Fig.1: Identification plot of incoming ion beam

Result:

Integrated Coulomb-dissociation cross-sections (CD) of 90±7 mb and 169 ± 13 mb up to excitation energy of 10 MeV for one neutron removal from ^{29}Na and ^{30}Na respectively have been extracted. For both the isotope, it has been found that only small part of one neutron CD cross-sections (~25%) populate the core, in its' excited state. A comparison of our experimental findings on the core excited states contributions in the ground state configuration with the shell model calculation using the MCSM suggests a lower limit of the sd-pf shell gap in ^{29,30}Na of around 4.8 MeV and 4.3 MeV respectively. A comparison with the direct breakup model, suggests ground state configurations of these nuclei are as ^{28}Na$_{gs}$(1$^+$) X $\nu_{s,d}$ and ^{29}Na$_{gs}$(3/2$^+$) X $\nu_{s,d}$, respectively. According to our experimental results, the valence neutron is occupying mainly *d* orbital for both the neutron-rich Na nuclei (N=18,19). Experimentally obtained spectroscopic factor (2.18± 0.3) for valence neutron in *d* orbital of ^{29}Na is in closer agreement with modified sd shell (USDB) calculation (2.18). On the other hand the same for ^{30}Na is different and experimentally obtained spectroscopic factor for valence neutron in *d* orbital is much reduced 2.09±0.28 compared to sd-shell (USDB) calculation (2.97). This could be tentatively, for particle hole configuration across the shell gap and valence neutron may occupy either *f* orbital or mixing of both *p f* orbital. Thus, it may be concluded that boundary of "island of inversion" has been started from ^{30}Na. It may be interesting to notice that Wildenthal et al. [6], observed that USD shell model calculation agreed well with measured mass and binding energy for ^{29}Na but did not fully reproduced the measured values for ^{30}Na. However more detail theoretical calculation is necessary to understand the nucleon-nucleon interaction for these neutron-rich nuclei near "island of inversion".

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