1p3/2 Proton-Hole State in 132Sn and Shell Structure Along N=82


The nucleus 132Sn is of particular interest for nuclear structure investigations since it is the only heavy neutron-rich doubly-magic far-near magic far below the valley of stability which is accessible for experimental studies. While 132Sn as well as the neighboring Sn (Z=50) and Sb (Z=51) isotopes have been studied in detail in the past, the experimental information for nuclei in the region below 132Sn is scarce. Important knowledge, e.g. with respect to the energies of the proton single-hole states in 132Sn, is still missing.

In an experiment performed in December 2012 as part of the EURICA campaign at the Radioactive-Isotope Beam Factory (RIBF), the neutron-rich nuclei 131,132Cd were produced by the in-flight fission of a 238U beam and implanted into the active stopper WAS3Ab. The γ rays emitted following the β decay of 131Cd and after β-delayed neutron emission of 132Cd were detected with the EURICA array comprising 84 germanium crystals. A single γ ray with an energy of 988 keV was observed in the decays of both 131Cd and 132Cd. It was placed to populate the known (1/2−) β-decaying isomer in 131In at an excitation energy of 365(8) keV thus defining a second excited state at 1353 keV. This newly identified state is preliminary assigned to have spin and parity of 3/2− and to correspond to the previously unknown 1p3/2 proton single-hole state with respect to the 132Sn core. A full account of the arguments which lead to this assignment is presented in Ref. 2).

Using the newly established 1p3/2 proton single-hole energy, shell-model calculations have been performed to calculate the energies of the first excited 2+ states and the proton gaps ∆2p [defined here as ∆2p = M(Z + 2, N) + M(Z - 2, N) - 2M(Z, N), with M(Z, N) the mass of a nucleus with Z protons and N neutrons] for the N=82 isotones below 132Sn as shown in Fig. 1. For comparison, Fig. 1 also shows the results of similar SM calculations performed for the N=50 isotones below 100Sn, in that case in comparison with available experimental information. While for the N=50 isotonic chain typical signatures of shell closures are observed at Z=38 and 40, for the

Fig. 1. a) and c): Energies of the first excited 2+ states, E(2+), and b) and d): proton gaps, ∆2p, in the even N=50 and N=82 isotones, respectively. The black lines (solid, dashed, and dotted) in c) and d) show the results of SM calculations assuming an increase of the 1p splitting by 0.5, 1.0, and 1.5 MeV, respectively.

disappear for the N=82 isotones below 132Sn. The disappearance of the proton sub-shell closures has its origin in the small energy gap between the 1p1/2 and the next single-particle orbital (SPO), independent of the character of the latter. Figs. 1 c) and d) show the reappearance of the sub-shell gap when increasing the energy separation between the 1p1/2 orbit and the next SPO.

Without the existence of pronounced proton sub-shell closures the N=82 isotones 120Sn and 122Zr should behave as mid-shell nuclei and consequently enhanced cross-shell excitations are expected to lead to a reduction of the N=82 shell gap in that region. Such a reduction would have a significant impact on r-process calculations and it is therefore concluded that preference should be given to mass models which indeed predict a reduction of the N=82 gap, such as the HFB24[5] approach.

References