# Evolution of the spin-orbit splitting from $^{16}$O to $^{22}$O and the role of tensor force

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**Abstract**

In the shell model framework, the two-body nuclear force can be divided into a central, spin-orbit (SO) and tensor parts. The vast majority of studies performed so far in stable nuclei of the nuclear chart show that the amplitude of the SO splitting scales with approximately A^(-2/3), due to the surface-dominant term of the spin-orbit force. The aim of this study, which goes far beyond stability, is to determine the evolution of the proton 0p3/2-0p1/2 SO splitting between the well-known 16O (N = 8) and the neutron-rich 22O (N = 14) nuclei. In addition to the role of the SO force, this evolution also depends on the contribution of the tensor force, which should lead to a further decrease of the SO splitting as the neutron 0d5/2 shell fills on the doubly magic 16O nucleus. The s509 experiment was conducted at the R3B beamline during the 2022 experimental campaign at GSI. The 22O nuclei were delivered via the FRS spectrometer and impinged a 5 cm thick cryogenic hydrogen target to induce neutron and proton quasi-free scattering (QFS) reactions. These reactions populated, among others, the neutron and proton hole states in 22O, leading to the 21O and 21N nuclei, respectively. The protons and neutrons arising from (p,2p) or (p,pn) reactions, the residual nuclei, and their associated decay products were detected using the versatile R3B setup in Cave C. This setup allowed a complete event-by-event reconstruction in inverse kinematics, including the identification and momentum determination of both the incoming nuclei and outgoing fragments. In addition, high-resolution gamma-ray and neutron spectroscopy was performed using the CALIFA and NeuLAND arrays, respectively. The combination of detectors within this experimental setup allowed the study of the decay of both bound and unbound states populated by these reactions, as well as the study of the angular momentum of the nucleons removed during the knockout reactions. The first part of this thesis focuses on the study of the N = 14 magicity of the 22O nucleus via the 22O(p,pn) reaction, probing the degree of correlation across the neutron 0d5/2-1s1/2 gap. The upper limit of the neutron occupancy of the valence 1s1/2 orbital is then estimated from gamma- spectroscopy and momentum analysis to be <1% with a confidence level of 68%. In addition, we have identified a new unbound state in 21O at Erel = 0.438(30) MeV, whose the strength and transverse recoil momentum are consistent with a 1/2^- state predicted by Shell Model calculations. The second part of this work is dedicated to the identification as well as the determination of the spectroscopic factor of the 0p states in the 21N nucleus, up to its two-neutron emission threshold, through the 22O(p, 2p) reaction. The population of the first known 3/2^-(1) bound state and two new resonances were observed using gamma- and one-neutron spectroscopy, respectively. The extraction of the associated spectroscopic factors allows the determination of the amplitude of the proton 0p1/2-0p3/2 gap (Z = 6) in 22O. This value is then compared with different calculations, including (ISM(YSOX)) or excluding (WS potential) the tensor interaction, in order to estimate its contribution to the evolution of the SO splitting.