Nuclear surface diffuseness of Ne and Mg isotopes in the island of inversion[†]

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It had been suggested in the literature,[1] that the island of inversion close to $N = 20$ and 28 arises because of the $\nu(sd)^{-2}(fp)^2$ intruder configurations. It was proposed that two neutrons from the sd-shell are excited to the fp-shell become so low in energy that they manifest as the ground state of $Z = 10$–12 and $N = 20$–22 nuclei. This proposition was confirmed by mass measurements and reactions involving neutron rich isotopes of Ne, Na and Mg, especially at RIBF. This change in occupation of nucleons in different energy levels not only results in large deformations but also affects the nuclear density profile, particularly the nuclear surface diffuseness. In this work, we attempt to systematically investigate the connection between the nuclear surface diffuseness and various spectroscopic information of Ne and Mg isotopes ($N = 19$–28) at or near the island of inversion. We calculate the density and spectroscopic information of Ne and Mg isotopes using the antisymmetrized molecular dynamics (AMD) model.[2,3] We then construct a two-parameter Fermi density distribution (2 pF), with adjustable radius and diffuseness parameters. These parameters are then estimated using two complementary methods - one analyzing the static structure and the other dynamical, in which reaction observables involving these nuclei are analyzed. In the first method, the optimized radius and diffuseness parameters of the 2 pF are estimated by minimizing the difference between densities obtained by AMD and 2 pF density distributions. In the second, both the AMD and 2 pF densities are taken as inputs to calculate the proton-nucleus elastic scattering differential cross section using the Glauber model. We then demand that the first peak position and its magnitude are reproduced for both these densities as prescribed.[4] We have verified that the parameters estimated using these complementary methods agree within a margin of 1–3%.

The nuclear surface diffuseness, *i.e.*, the diffuseness parameter of the 2 pF density of Ne and Mg isotopes extracted from the matter density distribution of AMD is plotted in Fig. 1. The diffuseness parameter has similar dependency on neutron number, illustrating the similarity in nuclear deformations for both Ne and Mg isotopes.[2,3] We observe that the neutron occupancy of

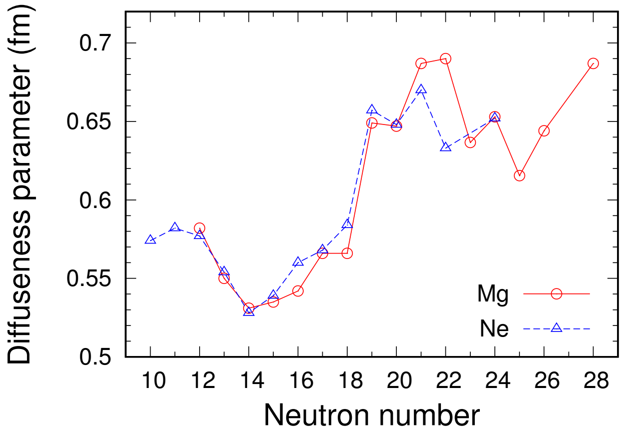

Fig. 1. Diffuseness parameters of Ne and Mg isotopes as a function of neutron number. The figure is adopted from the original article.[†]

the weakly-bound $1p_{3/2}$ orbit has a significant impact on the global behavior of the diffuseness parameter. The absence of intruder orbitals till $N = 18$ results in normal shell filling and hence diffuseness parameters are very similar to the standard value of 0.54 fm. The effect of the intruder orbitals begins to be felt from $N = 19$ onwards resulting in strong quadrupole deformation and mixing of p- and f-waves. ^{29}Ne and ^{31}Mg ($N = 19$) have predominant 2p3h configurations in which two particles are promoted from the sd- to pf-shell. The increasing occupation probability of the $1p_{3/2}$ orbit not only results in a large diffuseness but also the breakdown of the $N = 20$ and 28 magic numbers in this region. An exception, however, is noted for $^{35-37}$Mg where the filling up the holes in the deeply bound sd-shell somewhat compensates the increase in diffuseness due to filling up of the $1p_{3/2}$ orbit. Noticeably, for $N = 22$, ^{34}Mg has predominant 4p2h configuration, whereas ^{32}Ne has an admixture of 4p2h and 2p0h configurations. This could be the reason why ^{34}Mg is more diffused than ^{32}Ne.

In conclusion our work shows that information about the nucleus surface diffuseness in exotic neutron rich nuclei can be extracted from the first diffraction peak of nucleon-nucleus elastic scattering differential cross section.

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