Study Of Nuclei Using Infinite Nuclear Matter Model Of Atomic Nuclei

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Introduction

The Infinite Nuclear Matter Model (INM Model) of atomic nuclei [1]-[4] has been quite successful in dealing with ground state properties of nuclei. The local energy η in the model plays a vital role in this regard as it represents the individual character of a nucleus. In the thesis, we have exploited [7, 12] the differential equation satisfied by the local energy to obtain a similar equation for reduced transition probability $B(E2)\uparrow$ and the corresponding excitation energy $E2$ for transition from ground state to the first excited state for even-even nuclei. The differential equation model then is used to develop two recursion relations for $B(E2)\uparrow$ and $E2$ connecting separately three different neighboring even-even nuclei. The recursion relations are,in turn, used [11] to predict the $B(E2)\uparrow$ and $E2$ values for unknown nuclei using the values for known neighbouring nuclei adopting the combined data set of 325 even-even nuclides of both Raman et al.[5] and Pritychenko et al.[6]. Our model predictions both for known and unknown isotopes almost follow the isotropic trends of the experimental data and are in the same direction as in the case of other two theoretical models SSANM and FRDM. Finally, we apply the model predicted $B(E2)\uparrow$ values to identify[13] the possible existence of large deformations in the neutron- and proton-rich regions of nuclear chart from the calculation of deformation parameters, namely quadrupole deformation β_2, the ratio of β_2 to the Weisskopf single-particle $\beta_{2(sp)}$ called β_r and the intrinsic quadrupole moment Q_0.

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Result and discussion

Analyzing the individual cases, we find the values of the deformation parameter β_2 as 0.59 and 0.63 respectively at N = 20 and 22 for Ne (Z = 10). Despite N = 20 being a magic number and N = 22 is close to it, both these two n-rich isotopes are found to have such large values of β_2. On the other hand, β_r values of these isotopes are respectively 3.73 and 3.99, which are definitely larger than those of its own known neighbors. Thus such increase is a clear indication of the possible occurrence of higher deformations in both ^{30}Ne and ^{32}Ne, well-supported by the recent experimental observation of enhanced collectivity for ^{30}Ne and the resulting disappearance of N = 20 shell-closure by Yanagisawa et al. [8]. Even the neighboring nuclide ^{34}Mg has been also found to be highly deformed as its β_2 value is 0.50 in agreement with the experimental finding by Iwasaki et al. [9]. Incidentally this nuclide has also the same neutron number N = 22 as that of ^{32}Ne. Our close scrutiny also lead us to find possible occurrence of large collectivity for ^{60}Ti (Z = 22) as its β_2 value is 0.51, which is almost close to that of super deformation. Its β_r value has been found to be 7.11, which is again much larger compared to its neighboring known isotopes. Accordingly this n- rich isotope of Ti is most likely be heavily deformed despite its neutron number 38 being very close to the semi-magic number 40 and its proton number also being very close to the magic number 20, thereby clearly supporting the possible manifestation for the occurrence of another **Island of Inversion** at N = 40 caused by the intruder states from gd-shell [16].

Similarly such occurrences are also seen in case of $^{42,62,64}Cr$, $^{50,68}Fe$ and $^{52,72}Ni$ for β_2 and β_r respectively. For all these nuclei, the β_2 values lie in the range 0.29-0.41 and β_r values lying in the range 4.96-6.13 signifying large collectivity. Incidentally these predictions of ours are again well-supported by the recent experimental observation of increased quadrupole collectivity in ^{64}Cr and ^{68}Fe by Crawford et al. [10] and in $^{60,62}Cr$ by Sorlin et al [16]. In all these n- rich isotopes including ^{60}Ti as stated above, the N = 40 sub-shell closure most possibly gets broken due to intruder orbitals $g_{9/2}$ and $d_{5/2}$ leading to strong collectivity in agreement with the conclusions arrived at by Sorlin et al. [16].

Concerning the isotopes of Kr, Sr and Zr (Z = 36, 38 and 40), we find the exotic isotopes $^{70,72,96}Kr$, $^{74,76}Sr$ and $^{78,80,106,108}Zr$ to have values of β_2 lying in the range 0.40-0.49, while those of β_r lie in the range 10.3-11.6. Obviously, such values of β_2 for these isotopes are quite large enough to signify high deformations in them. It is quite satisfying to note here that our present finding of large deformation with a β_2 value of 0.4 for ^{80}Zr in fact has been well-corroborated by Lister et al. [15] long back experimentally. One can also see that the n- rich isotope ^{102}Sr can also be treated as highly deformed as its β_2 and β_r values are almost close to the above ranges. For the neighboring element Mo, we also find relatively larger values of β_2 lying in the range 0.39-0.46 for the isotopes $^{82,84,110,112}Mo$, whereas their β_r values lying in the range 10.3-12.2 are quite large enough compared to their known neighbors qualifying them to have large deformations. Prediction of such strong collectivity for the exotic isotopes ^{108}Zr and ^{112}Mo may be again connected to the possible existence of another **Island of Inversion** by the breaking of the N = 70 sub-shell closure by the intruder states from hfp-shell. Thus the existence of two **Islands of Inversion** already detected experimentally with the breaking of shell closures at N = 20 and N = 40 and our present prediction of another one at N = 70 sub-shell closure appears to be a general feature of nuclear dynamics in the exotic n- rich regions of the nuclear chart.

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