Nuclear Structure study of the element Z=114,120 and 126 using Intrinsic Quadrupole Moment

T. Sahoo[1],* R. L. Nayak[2], and A. Acharya[3]
[1,2,3] *Veer Surendra Sai University of Technology,Burla,Odisha-768018*

Introduction

Now a days it is a big challenge to the researchers to establish the existence of superheavy elements and find the magicity in the valley of superheavy. But along with it is most important to study the structural description of such nuclei. Quadrupole moment is a very good tool in determining the shapes of these nuclei . The transition of the particle from the ground state to excited state within the nucleus leads to the spatial extension of the charge distribution. In order to have a qualitative idea about the shape of a spatially extended particle one has to determine its intrinsic quadrupole moment (Q_0)[1]. Q_0 is the moment that is obtained in a body fixed coordinate system that rotates with the nucleus. Beside the intrinsic quadrupole moment there is also a moment known as spectroscopic quadrupole moment (Q_s) that results due to the change in angular moment (J). But some nuclei have permanent deformation in its ground state($J = 0$) all the orientation of a deformed $J = 0$ nucleus are equally probable, which results in a spherical charge distribution in the ground state and a vanishing quadrupole moment ($Q_s = 0$). Nevertheless, the nucleus can have an intrinsic quadrupole moment. Hence, the shape of a nucleus at first is linked to the intrinsic and not to spectroscopic quadrupole moment.[2]

Theory

Considering the homogeneous charge distribution the intrinsic quadrupole moment (Q_0) is given as[1]

$$Q_0 = \frac{3ZR^2}{\sqrt{5\pi}}\beta \qquad (1)$$

Where Z is the atomic number, $R = 1.2A^{\frac{1}{3}}$ and the shape parameter β.
Since the deformation is axially symmetry the nucleus is considered as a charged ellipsoid. So, it is necessary to measure the varying length of semi major axis(a) and semi minor axis(b) with atomic mass number(A) using the formula [3]

$$Q_0 = \frac{2}{5}Z(a^2 + b^2) \qquad (2)$$

Result and Discussion

The main objective of this paper is to describe the nuclear structure deformation for the isotopic chain of the element Z=114,120 and 126 around their neutron magic combination N = 178/184 for Z=114 and 120 and N = 184/198 for Z= 126 as predicted by us [4] in the mass region A= 284-304 , 290-310 and 306-326 respectively . The structural property is studied through the intrinsic quadrupole moment Q_0 as a function of shape parameter (β) considered from finite range droplet model (FRDM). Along with it we have also calculated the Q_0 in terms of semi-major axis (a) and semi-minor axis(b). Here we took the ratio of 'a' and 'b' for the same isotopes in order to have a clear idea of the deviation of shape of the nucleus from the spherical shape. If Q_0 is negative $(\frac{a}{b}) < 1$ indicating oblate shape if Q_0 is positive $(\frac{a}{b}) > 1$ indicating prolate shape and if Q_0 is zero $(\frac{a}{b}) = 1$ indicates the spherical shape.

In Fig. 1 the intrinsic quadrupole moment Q_0 is plotted against the atomic mass number(A)using eq. 1 . We can see there is no

*Electronic address: `trupti9vssut@gmail.com`

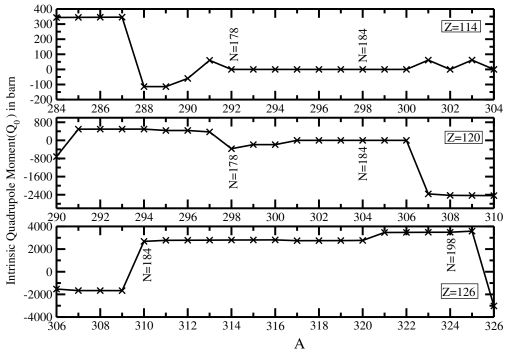

FIG. 1: Intrinsic quadrupole moment Q_0 for Z= 114,120,126.

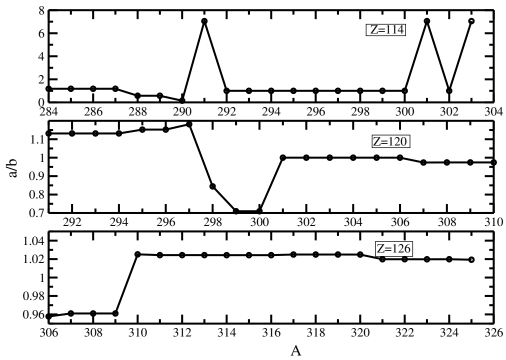

FIG. 2: Ratio of Semi-major axis(a) and semi-minor axis(b) for Z=114,120,126.

definite sequence for the variation of Q_0 with increase particle number. For Z=114 with N=178 and 184, there is no quadrupole moment which indicates the nucleus is spherical in shape. For Z=120 with N=178, it is negative whereas with N=184 it is zero indicating the oblate and spherical shape respectively. For Z=126 with N = 184 and 198 both the isotope have positive Q_0 value showing prolate shape.

In Fig. 2 the ratio of semi-major axis(a) to semi-minor axis(b) is plotted against atomic mass number (A) using eq 2. We can say that for Z=114 in the mass region A=284 to 304, the shape of nucleus changes gradually from prolate to oblate but at A=292 the shape suddenly changes to spherical which remains same up to A=300 then from A=301-304 the shape randomly changes. A quite similar pattern is obtained for Z=120 isotopes, the shape of these nucleus gradually changes from prolate to oblate for A=291-300 then for A=301-306 the spherical shape is maintained then after A=300 the shape becomes oblate. Now focusing on the element Z=126 we observe none of the isotope are in spherical shape they are either prolate or oblate shape.

We can say here the indefinite change in the shape of these superheavy elements may occur due to the rigorous moments of the large number of particles inside the nucleus.

Conclusion

Generally the most stable isotope or the magic number nuclei are expected to be spherical in shape but in our study we found that not all the magic nuclei are in spherical shape rather some attains their minimum energy in non-spherical form. Moreover in this high mass region we cannot talk about the pattern of the changing shape this may be due to our insufficient analysis of these isotopes. As we all are aware of the fact that the superheavy elements exist due to the shell effect hence, along with the intrinsic quadrupole moment (Q_0) the spectroscopic quadrupole moment(Q_s) should be taken into account to have a better idea about the structure and stability of the superheavy elements.

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