Shape evolution in odd-A Ge isotopes: the effect of $g_{9/2}$ orbital

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Introduction

Recently, the experimental results show interesting shape properties for the Zn (Z = 30) and Ge (Z = 32) nuclei near N = 40 [1-4]. The shape evolution in the odd-A isotopes in these nuclei is governed by the neutron $g_{9/2}$ orbital. The systematic of the $g_{9/2}$ orbitals in Ge isotopes, shown in Fig.1, indicates that $9/2^+$ is the ground state for the N = 41 isotope ^{73}Ge and its excitation energy increases on either side of it. So, N = 40 behaves like a transitional point in Ge isotopes.

The shape evolution of the Ge isotopes as a function of the $g_{9/2}$ occupation of the odd neutron has been investigated in this work. For this, the total Routhian surfaces (TRS) were calculated for the positive parity neutron configuration in the odd-A Ge isotopes spanning the entire *fpg* shell of the neutrons between the shell closures at N = 28 and 50. Calculations are also performed for ^{59}Ge (N = 27), for which the neutron Fermi level lies below the N = 28 shell closure, for comparison. The method described in Ref. [5,6] and references there in, has been adopted in this work.

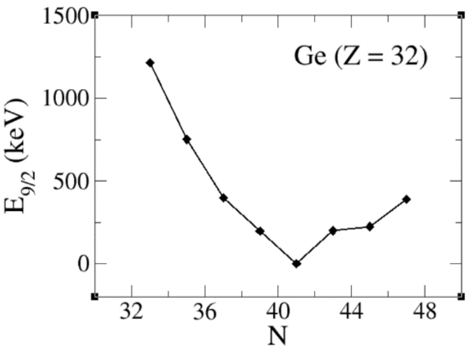

Fig.1: Systematics of the measured excitation energy ($E_{9/2}$) of the $9/2^+$ state in Ge isotopes as a function of neutron number N.

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Results and Discussion

The results are summarized in Table 1. It contains the deformation parameters β_2 and γ for different nuclei, corresponding to the minimum in the TRS. These parameters determine the shapes of these nuclei for the one quasi-particle $\nu g_{9/2}$ configuration. Here, the deformation parameter β_2 gives the amount of deformation and γ gives the nature of deformation. In the Lund convention, used here, $\gamma = 0^o$ (-60^o) corresponds to collective prolate (oblate) shapes and γ value in between these limits signifies triaxial shape with $\gamma = \pm 30^o$ is considered as maximum triaxiality.

Table 1: Deformation parameters of the Ge isotopes obtained in this work at $\hbar\omega$ = 0.240 MeV.

N	Nucleus	β_2	γ
27	^{59}Ge	0.348	-58.1
29	^{61}Ge	0.394	3.1
31	^{63}Ge	0.344	4.5
33	^{65}Ge	0.284	36.5
35	^{67}Ge	0.274	86.0
37	^{69}Ge	0.256	-5.2
39	^{71}Ge	0.261	-32.5
41	^{73}Ge	0.241	-33.5
43	^{75}Ge	0.232	-37.5
45	^{77}Ge	0.124	-19.4
47	^{79}Ge	0.130	-28.0
49	^{81}Ge	0.114	-116.0

It is interesting to note from Table 1 that ^{59,61}Ge has oblate and prolate shapes, respectively, with large deformation parameter β_2 compared to the other isotopes. This may be understood from the fact that certain Nilsson components of the $g_{9/2}$ orbital can be accessible for the odd neutron in these isotopes, only for large β_2. It can also be observed that the deformation parameter β_2

decreases with the increase in neutron number as the $g_{9/2}$ orbital becoming more accessible for near spherical shape.

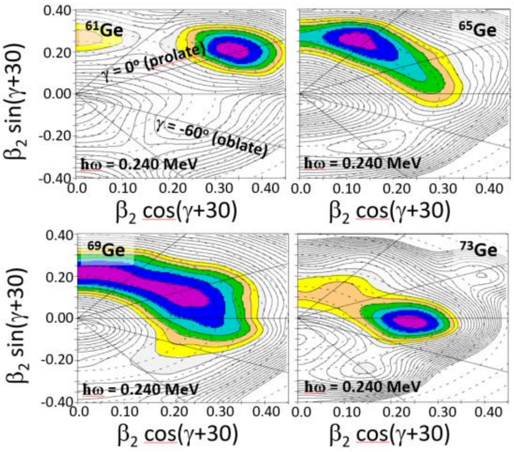

Fig. 2: TRS plots for ^{61,65,69,73}Ge calculated at the rotational frequency ħω = 0.24 MeV. The contours are 250 keV apart.

The TRS plots for some of the Ge isotopes, calculated in this work for the 1 quasi-particle positive parity, positive signature configuration, are presented in Fig.2. The large prolate shapes for $^{61-65}$Ge are clearly evident in this plot (TRS plot for ^{63}Ge is similar to that of ^{65}Ge but is not shown in Fig.2). As the neutron number increases, the minimum in the potential energy shifts towards large triaxial shape for neutron number around N ~ 40, as shown in the plot for ^{73}Ge, through gamma-soft shape, as shown for ^{69}Ge. The shape of ^{71}Ge (not shown in Fig.2) and ^{73}Ge with N = 39 and 41, respectively, becomes triaxial with γ values close to maximum triaxiality (see Table 1). Therefore, the lowering of the $9/2^+$ energy of the Ge nuclei around N = 40 (as shown in Fig. 1) perhaps, due to their triaxial shapes. It would be interesting to investigate the nature of the $g_{9/2}$ orbital as a function of the deformation parameter γ. With further increase of neutrons towards N = 50, both triaxiality and deformation decrease towards near spherical shape.

Structural evolution of the Ge isotopes as a function of rotational frequency has also been studied in this work and the TRS plots for two isotopes, ^{61}Ge and ^{69}Ge, calculated at ħω = 0.48 MeV are shown in Fig.3. It can be seen that the prolate shape in ^{61}Ge at lower ħω continues to retain its shape even at higher rotational frequency, though the β_2 value reduces slightly. On the other hand, a significant change in shape is observed for ^{69}Ge and ^{67}Ge isotopes. The gamma-soft shapes in these nuclei at lower frequency change to a near prolate shape with larger β_2 at higher frequency. This indicates that the gamma-soft shape stabilizes at an axially symmetric prolate shape by the effect of the coriolis force in these isotopes with N = 35, 37.

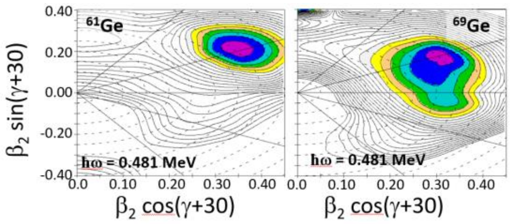

Fig. 3: Same as Fig.2 but for ^{61,69}Ge at ħω = 0.48 MeV.

Conclusion

The shape evolution of the positive parity configuration in the odd-A Ge isotopes has been studied by the TRS calculations. The calculations are done for neutron number ranging between two shell closures at N = 28 and 50. A change in shape from large prolate for the neutron deficient isotopes near N = 28 to a near spherical one close to N = 50 has been obtained. The isotopes with neutron number around N = 40 are predicted to be triaxial. The gamma-soft shapes for ^{65,69}Ge at lower rotational frequency get stabilized to a near prolate shape at higher frequency. The experimental evidence of triaxial shapes and shape evolution will be interesting.

References

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