Study of ground-state shapes of even-even tellurium isotopes in relativistic Hartree-Bogoliubov model

*Shivali Sharma[1],Rani Devi[1]and S.K.Khosa[2]
[1]*Department of Physics, University of Jammu, Jammu-180006, India*
[2]*Department of Physics and Astronomical Sciences, Central University of Jammu, Jammu-181143, India*
**email: shivalisharma0004@gmail.com*

Introduction

The advancement in experimental and computational techniques provides an opportunity to investigate the ground state properties of whole nuclei of the nuclear chart. Ground state properties of medium-heavy and heavy nuclei have been the focus of interest in both theoretical and experimental fields of nuclear physics as these properties provide key information about the structure of nuclei. Structure properties of medium-heavy complex nuclei with many active valence nucleons, now-a-days is best described by self-consistent mean-field models [1]. These methods enable us to probe the nuclear structure with universal energy density functionals. In the present paper, the relativistic Hartree-Bogoliubov (RHB) model [2] with density dependent point coupling interaction and separable pairing force is used to study the ground state shapes and properties of even-even $^{130\text{-}144}$Te isotopes. The ground state properties like binding energy, two neutron separation energies, charge radius and root mean square radii are also obtained.

Theoretical framework

In the present work, RHB formalism with density dependent point coupling interaction (DD-PC1) is employed to explore the ground state properties of the $^{130\text{-}144}$Te isotopes. Earlier this formalism has been used with different interactions and it provides excellent description of the ground state properties of nuclei in the nuclear chart. The DD-PC1 [3,4] interaction includes the pairing correlations that are imposed in the BCS approximation with empirical pairing gaps. For the details of formalism see refs. [2-4]. The binding energy maps of the tellurium isotopes as a function of quadrupole deformation are attained by imposing constraints on both triaxial and axial quadrupole moments. It is done by the method of quadratic constraint along with an unrestricted variation of the function

$$\langle \hat{H} \rangle + \sum_{\mu=0,2} C_{2\mu}(\langle \hat{Q}_{2\mu} \rangle^2 - q_{2\mu})^2 \qquad (1)$$

where $\langle \hat{H} \rangle$ represents total energy and $\langle \hat{Q}_{2\mu} \rangle$ is the expectation value of the mass quadrupole operators

$\hat{Q}_{20} = 2z^2 - x^2 - y^2$ and $\hat{Q}_{22} = x^2 - y^2$, (2)

$q_{2\mu}$ is the constrained value of the multipole moment and $C_{2\mu}$, the corresponding stiffness constant. Moreover, the quadratic constraint adds an extra force term $\sum_{\mu=0,2} \lambda_\mu \hat{Q}_{2\mu}$ to the system, where $\lambda_\mu = 2C_{2\mu}(\langle \hat{Q}_{2\mu} \rangle - q_{2\mu})$ (3)

for a self-consistent solution. This term is necessary to force the system to a point in deformation space different from a stationary point. The binding energy maps conform to self-consistent solutions of the RHB equations that are obtained by the nucleon spinors and the meson fields in the basis of a 3D harmonic oscillator.

Results and discussion

In Fig. 1, the triaxial quadrupole binding energy maps, obtained by self-consistent RHB calculations in the (β, γ) plane $(0° \leq \gamma \leq 60°)$ for $^{130\text{-}144}$Te are displayed. All the energies have been normalized with respect to the binding energy of the absolute minimum and surface contours join the points of same energy. A careful examination of the binding energy maps as function of quadrupole deformation parameter (β) shows the shape transition from spherical $^{130\text{-}134}$Te to axially prolate deformed $^{136\text{-}144}$Te. The beta values obtained from the binding energy maps are

in the range 0.10 to 0.20 for $^{136\text{-}144}$Te. However, these higher mass Te isotopes do not show the role of triaxiality in the present calculations.

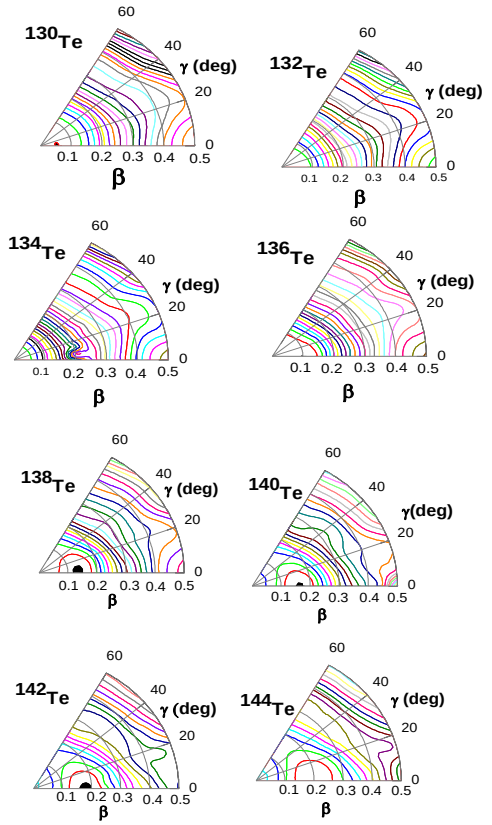

Fig.1 RMF triaxial quadrupole binding-energy (in MeV) maps of the even-even$^{130\text{-}144}$Te isotopes in the β-γ plane($0 \leq \gamma \leq 60°$) .

On analyzing these trends in binding energy maps of $^{130\text{-}144}$Te isotopes, one can clearly describe the shape transition in tellurium isotopic mass chain as one moves form A=130 to A=138. In Fig. 2, the two-neutron separation (S_{2n}) and differential two neutron separation energies (dS_{2n}) are displayed as a function of neutron number (N). The calculated results are compared with the experimentally available data. The two neutron separation energies are obtained by using the binding energies calculated from RHB model with DDPC1 parameter set in the relation

$$S_{2n} = E(Z,N) - E(Z,N-2).$$

As the neutron number increases the S_{2n} energy decreases and kink appears at the spherical neutron shell closure at N=82. For better explanation of these sharp discontinuities at neutron spherical shell closure, we calculate differential two neutron separation energy by the relation

$$dS_{2n}(Z, N) = \frac{S_{2n}(Z,N+2) - S_{2n}(Z,N)}{2}$$

A deep valley is observed at N=82 in the plot of dS_{2n}. This sharp fall in dS_{2n} at N=82 indicates that energy required to remove two neutrons from (Z,N_{magic}) nucleus is larger than energy required to remove the two neutrons from the nucleus ($Z,N_{non\text{-}magic}$). This also provides a hint towards the more nuclear structure features in this isotopic chain. From Fig. 2, one can observe that calculated results S_{2n} are in reasonable agreement with those calculated from experimental data [5]. It shows the conjecturing power of the calculation for the correct evolution of shell structure.

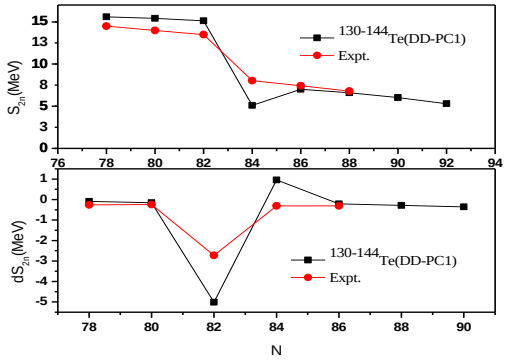

Fig.2 Comparison of experimental (expt.) and calculated (Th.) S_{2n} and dS_{2n}.

We acknowledge IUAC, New Delhi for allocation of High performance computing facility.

References

[1] D.Vretenar *et al.*, Phys. Rep.**409**, 101 (2005).
[2] T. Niksic *et al.*, Phys. Rev. C**81**, 054318 (2010).
[3] T. Niksic *et al.*, Phys. Rev. C**78**, 034318 (2008).
[4] P.W.Zhao *et al.*, Phys. Rev. C**82**, 054319 (2010).
[5] M. Wang *et al.*, Chin. Phys. C**36**, 1603 (2012).