Study of neutron rich tellurium isotopes by using density dependent meson coupling interaction

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Introduction

In recent years, analysis of nuclear ground state properties and nuclear structure phenomena has been extensively done by Relativistic Mean Field (RMF) models. They are widely employed to study the nuclei in the beta stability as well as far from the beta stability regions [1]. Phase shape transition is one of the most important factors in the study of these nuclei, especially the ones lying near the shell closure Z=50 [2].

The shape transitions and ground state properties of Te isotopic mass chain have already been investigated theoretically by using density dependent meson exchange (DD-ME2) and density dependent point coupling (DD-PC1) parameterization [3]. In order to check the validity of this model with a different interaction, the extensive study on the ground state shapes and properties of axially deformed $^{130-144}$Te isotopes has been done by using density dependent point coupling (DD-PCX) effective interaction.

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Theoretical Framework

In the present work, the study of ground state shape and properties of neutron rich Te isotopic mass chain is done by Relativistic Hartree-Bogoliubov (RHB) formalism with density dependent point coupling DD-PCX interaction. The calculations are done by imposing the constraints on axial quadropole moments. It has been carried out by the method of quadratic constraints which uses unrestricted variation of function,

$$< \hat{H} > + \sum_{\mu=0,2}^{n} C_{2\mu}\left(< \hat{Q}_{2\mu} > - q_{2\mu}\right)^2$$

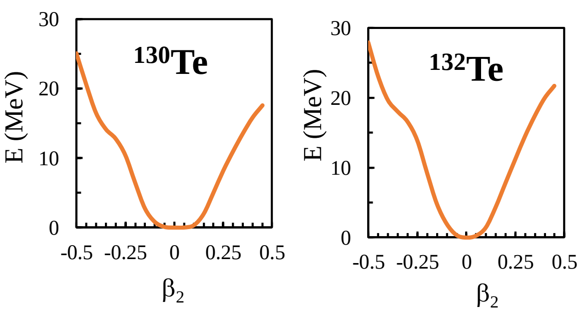
where <Ĥ> represents total energy and $<\hat{Q}_{2\mu}>$ is the expectation value of the mass quadrupole operators.

$$\hat{Q}_{20} = 2z^2 - x^2 - y^2 \quad \text{and} \quad \hat{Q}_{22} = x^2 - y^2$$

$q_{2\mu}$ is the constrained value of multipole moment and $C_{2\mu}$ is the corresponding stiffness constant. Also, the quadratic constraint adds an extra force term $\sum_{\mu=0,2} \lambda_\mu \hat{Q}_{2\mu}$ to the system, where $\lambda_\mu = 2C_{2\mu}\left(< \hat{Q}_{2\mu} > - q_{2\mu}\right)^2$ for a self-consistent solution. This term is necessary to force a system in deformation space different from a stationary point.

Results

Fig. 1 shows the two dimensional potential energy surfaces (PES) plots obtained from self-consistent RHB formalism for even-even $^{130-144}$Te isotopes. The normalization of all the energies has been done with respect to the absolute minimum binding energy. After careful investigation of these PES plots, it can be seen that primary minima is obtained at deformation parameter (β_2) = 0, 0, 0, 0.15, 0.15, 0.20 for ^{130,132,136,138,142,144}Te isotopes, respectively. From the above observation, it can be interpreted that there is a shape transition from spherical $^{130-136}$Te isotopes to axially deformed prolate $^{138-144}$Te isotopes. In ^{142,144}Te isotopes there is also a second minima obtained at β_2 = -0.10, -0.15, respectively. Therefore, there is also a possibility of oblate deformation at higher energies in ^{142,144}Te isotopes.



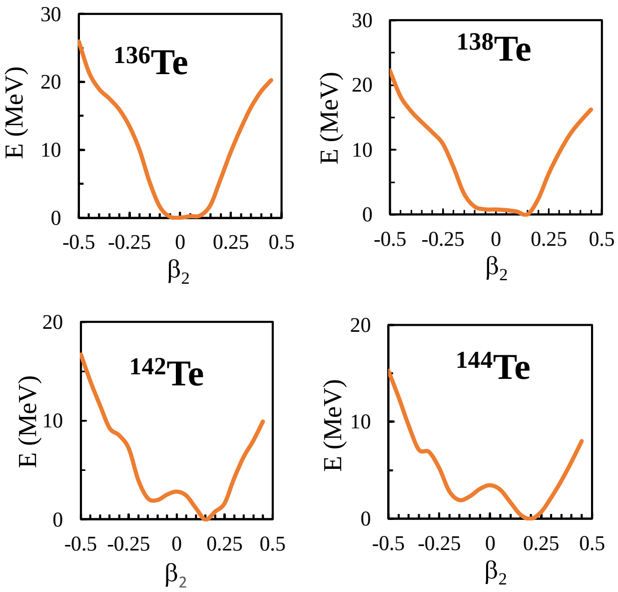


Fig. 1 The PES plots obtained with the help of DD-PCX interaction, as a function of deformation parameter (β_2) and energy (E) of $^{130-144}$Te isotopes.

Table 1 shows the comparison of average binding energy ($\bar{B}$) obtained from RHB formalism with the available experimental data [4]. The calculated results are reproduced well with the observed systematics. From this table, it can be seen that as the neutron number increases, there is a gradual decrease in average binding energy. An abrupt decrease in $\bar{B}$ values is observed after neutron number (N) = 82. This shows the existence of shell closure at N = 82.

In table 1, the comparison of charge radii (R_c) calculated with the help of RHB formalism is also made with the available experimental data [5]. There are few isotopes for which experimental values of R_c are not available but their values are predicted theoretically. After careful investigation of the table, it is clear that for neutron rich Te isotopes, the values of neutron radii (R_n) is larger than the proton radii (R_p). The large values of R_n are analogous to the decrease in average binding energy for $^{130-144}$Te isotopes. The available experimental data have been reproduced well by the current study.

Table 1: The comparison of experimental (exp) and theoretical (th) average binding energies, charge radii, proton and neutron radii [4, 5].

A	**$\bar{B}^{exp}$**	**$\bar{B}^{th}$**	**R_c^{exp} (fm)**	**R_c^{th} (fm)**	**R_n^{th} (fm)**	**R_p^{th} (fm)**
130	8.43	8.43	4.742	4.746	4.84	4.678
132	8.41	8.42	4.75	4.757	4.866	4.69
134	8.38	8.40	4.757	4.768	4.89	4.701
136	8.32	8.32	4.782	4.786	4.934	4.718
138	8.25	8.24		4.818	4.986	4.751
140	8.18	8.17		4.843	5.03	4.777
142	8.11	8.09		4.865	5.071	4.799
144		8.01		4.887	5.114	4.821

Summary

In the present study, self-consistent RHB calculations by using DD-PCX interaction have been performed to study the shape evolution and ground state properties of neutron rich $^{130-144}$Te isotopes. The average binding energies, charge radii, neutron and proton radii have been calculated. The calculated systematics are in good agreement with the experimental results and have a possibility of oblate deformation at higher energies for $^{142-144}$Te isotopes.

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