Cranking study of deformation systematics of some doubly-even barium isotopes

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Introduction

During the past about couple of decades, many theoretical studies in the mass A ~ 130 region were carried out by means of various phenomenological models. So, one of the goals of the present study is to test the applicability of Cranking Hartree-Fock-Bogoulibov model in the mass region of A ~ 130 by comparing the calculated results with some previous experimental data. Yrast levels for a chain of doubly-even Barium isotopes in the mass range ~ 130 are investigated at both low and intermediate angular momenta. In the present work, along with the description of the yrast spectra, some other important nuclear structure properties like deformation systematics, intrinsic quadrupole moments and reduced transition probabilities of these barium isotopes have also been presented.

Outline of the Model

The brief philosophy of the presently used CHFB framework has been presented in this section. The Hamiltonian used in the CHFB calculations is of the form:

$$H = H_0 - \lambda N - \omega J_x$$

Where H_0 is the single-particle Nilsson Hamiltonian , λ is the lagrangian multiplier having its physical interpretation related to Fermi-energies, ω is the frequency by which the nuclei is forced to crank or rotate about an axis and J_x is the angular momentum along rotation axis.

In the present work, the doubly magic nuclei tin ($_{50}Sn^{100}$) has been taken as the inert core and the valance space spanned by $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $2f_{7/2}$, $1g_{7/2}$, $1h_{9/2}$, and $1h_{11/2}$ orbits for the proton and neutron has been selected. The spherical single particle energies (S.P.E's) that have been employed (in MeV) are: $(3s_{1/2})$ = 1.40, $(2d_{3/2})$ = 2.0, $(2d_{5/2})$ =0.0, $(2f_{7/2})$ =10.9, $(1g_{7/2})$ =2.50, $(1h_{9/2})$ =11.5, $(1h_{11/2})$ =4.0 and $1i_{13/2}$= 13.5. The S.P.E's of $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $1g_{7/2}$, and $1h_{11/2}$ are exactly the same as those employed by Vergados and Kuo [1] as well as Federman and Pittel [2]. The two body interaction that has employed is pairing plus Quadrupole-Quadrupole type [3]. Besides this the strength of like (n-n) and unlike (n-p) particles of Quadrupole-Quadrupole interaction is taken to be :

$$\chi_{nn}\,(\chi_{pp}) = -0.011\,MeVb^{-4}$$

$$\chi_{np} = -0.022\,MeVb^{-4}$$

for all the isotopes under study.

Where $b = \sqrt{\frac{\hbar}{m\omega}}$ is the oscillator parameter.

The strength for pairing interaction was fixed through the approximate relation

$$G = (18\text{-}21) / A$$

The results of the present calculations for doubly even barium are presented in the following figures and tables.

i) **Yrast Spectra**

In Fig. 1, the comparison of the yrast spectra obtained by the CHFB calculations with the experimental energy levels [4] has been presented for ^{126}Ba and rest of the figures will be presented in the symposium.

ii) **Deformation Systematics & Intrinsic Quadrupole Moments**

Grodzins [5] suggested an empirical relation, according to which the energy of the first excited state (E_2) of even-even nuclei is inversely related to intrinsic quadrupole moments. Also, it has been found from the literature that E4/E2 ratio describes the deformation systematics and is directly related to the deformation of the nuclei. Intrinsic quadrupole moments and E4/E2 ratios for $^{126\text{-}136}Ba$ isotopic mass chain has been presented in the Table 1.

iii) **B(E2;0$^+$→2$^+$) Transition Probabilities of $^{126-136}$Ba isotopes**

Table 2 shows the comparison between the experimental [6] and the theoretical results obtained for the reduced transition probabilities B(E2↑) of $^{126-136}$Ba isotopes, which is known to be a stringent test of the model. The complete picture of these calculations will be presented and discussed during the symposium.

Conclusions:

From the results of the calculations mentioned above, it is found that:

- CHFB technique provides a good description of the low lying spin states of these barium isotopes when compared with the experimental levels.
- The values of intrinsic quadrupole moments obtained from CHFB calculation show a gradual decrease as one moves from ^{126}Ba to ^{136}Ba indicating, thereby, a decrease in the degree of deformation as one moves from ^{126}Ba to ^{136}Ba, which is in agreement with the experimental data and hence Grodzins rule is satisfied .
- Reduced transition probabilities obtained in the present calculations are in very good agreement with the experimental data.

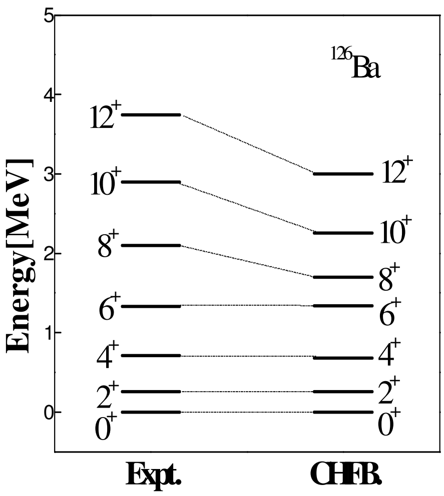

Fig. 1 Yrast Spectra of ^{126}Ba isotope.

Table 1: Deformation Systematics of $^{126-136}$Ba isotopes.

Nucleus	Intrinsic quadrupole moments		E_4/E_2 Ratio	
	Q_π	Q_ν	Expt.	CHFB.
^{126}Ba	27.99	44.61	2.7	2.64
^{128}Ba	27.95	44.52	2.62	2.52
^{130}Ba	27.70	39.71	2.52	2.48
^{132}Ba	27.64	36.42	2.42	2.42
^{134}Ba	27.41	32.43	2.317	2.32
^{136}Ba	27.11	29.43	2.27	2.26

Table 2: Reduced Transition Probabilities of $^{126-136}$Ba isotopes.

Nucleus	Transition Probabilities B(E2;0$^+$→2$^+$) (in units of e^2b^2)	
	CHFB	Expt.
^{126}Ba	1.34	1.75
^{128}Ba	1.32	1.48
^{130}Ba	0.81	1.1
^{132}Ba	0.76	0.8
^{134}Ba	0.68	0.6
^{136}Ba	0.66	0.4

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