Transitional nature of Strontium Isotopes

Mansi Saxena[1,*], S. Mandal[1,]
[1]*Department of Physics & Astrophysics, University of Delhi-110007.*
* *email: mansi.aqua@gmail.com*

Introduction

Interacting Boson Model [1] has been very successful in describing properties of many transitional nuclei. Strontium is a transitional nucleus and shows several interesting characteristics. The group structure of IBM allows to study the nature of the phase transitions between the three limiting cases namely SU(5), O(6) and SU(3). SU(5) denotes the spherical vibrator (β=0; where β and γ are the classical Hill- Wheeler parameters), SU(3) is the axially symmetric rigid rotor (β>0, γ=0°) and O(6) is the gamma – soft rotor (β>0, with a flat potential in γ). Spherical vibrators are usually found close to closed shells and have $R_{4/2} = E_{4+}/E_{2+} \sim 2$. Rotors are found near mid shell having $R_{4/2} \sim 3.3$, while gamma-soft rotors have $R_{4/2} \sim 2.5$.Any nuclei whose $R_{4/2}$ ratio lies between the three limiting cases can be classified as transitional. Earlier, IBM 2 has been successfully used to analyze the energy spectra and B(E2) values for the even – even isotopes of Strontium [2].

In the present report, we are reporting the calculation of Potential Energy Surface (PES) for the Sr isotopes. It is an extension of our previous work. Our earlier work showed a clear indication of varying structure for Sr isotopes from a deformed rotor to a spherical vibrator. It is further studied using the PES diagrams.

Interacting Boson Model – 2

In the Interacting Boson Model – 2, the nucleus is described as a system of two types of interacting bosons namely the proton (π) and neutron (ν) boons. In our calculations we have used the following IBM 2 Hamiltonian

$$H = \epsilon (n_{d\pi} + n_{d\nu})+ \kappa Q_{\pi}.Q_{\nu} + \lambda M + H_{\pi\pi} + H_{\nu\nu}$$

where ϵ is the energy splitting between the s and d state. $n_{d\pi}$ and $n_{d\nu}$ are the no. of proton and neutron d boson respectively. κ and λ represent the strength of the quadrupole – quadrupole interaction term and the Majorana type exchange operator respectively. $H_{\rho\rho}$ ($\rho=\pi,\nu$) gives the two boson interaction among like bosons. The quadrupole operator is given as

$$Q_{\pi,\nu} = (d^{+}s + s^{+}d)^{(2)}_{\pi,\nu} + \chi_{\pi,\nu}(d^{+}d)^{(2)}_{\pi,\nu}$$

In this paper we have followed two description and studied the geometrical interpretation of IBM-2 and plotted PES as a function of β and γ parameters [3,4]. In Sr nuclei the proton bosons are particle like and neutron bosons are hole like and therefore the neutrons and protons are likely to have opposite intrinsic quadrupole deformation. This shows in the difference of signs for $\chi_{\rho}(\rho=\pi,\nu)$.

Results of the IBM 2 calculation

In the first calculation the general IBM-2 Hamiltonian was used and written in terms of the conventional classical geometrical variables that is β and γ. The potential energy is formulated as a function of β_π, χ_π, β_ν and χ_ν.

We have used the IBM -2 parameters (ϵ, κ, χ_π, χ_ν) for Sr isotopes as derived earlier[2]. To study the shape of these nuclei we have applied the equation to even isotopes of Sr and plotted the PES diagrams. The condition for minima of potential surface was obtained by setting a common value for $\chi_\nu = \chi_\pi = 0$.

Fig.1 shows the contour plots for Sr isotopes as a function of β_π and β_ν.

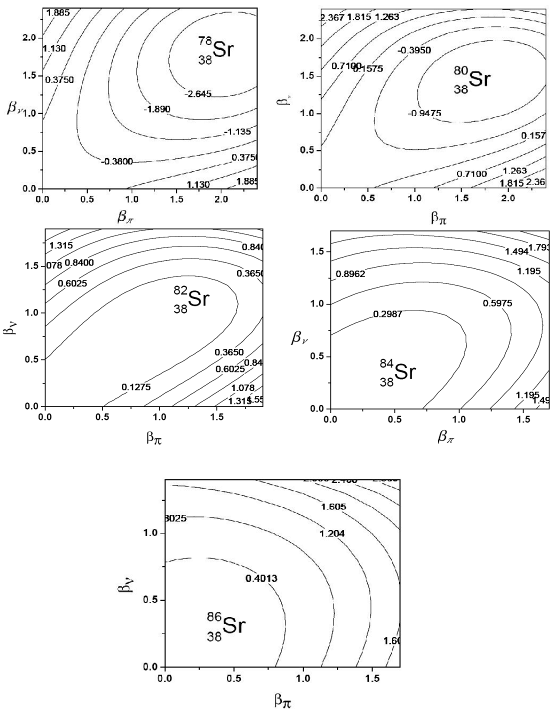

Fig. 1 Contour plots of $V_{\pi\nu}(\beta_\pi, \beta_\nu\ \chi_\pi = \chi_\nu = 0)$ against β_π and β_ν for Sr isotopes. The contour energies are given in MeV.

Another method has also been used for plotting PES diagrams [4]. The Skyrme interaction was used in the calculation along with the IBM hamiltonian. A coherent state formalism has been used to obtain the potential energy. We have assumed that β and γ take the same value for neutron and proton. In the first approximation, both β and γ would have the same shape[4].

Fig.2 shows the plots of potential energy surfaces as a function of the deformation parameter. The minima for ^{84}Sr is at the origin of the coordinate, indicating that the shape is spherical. Also the minima for ^{86}Sr lie at the origin indicating a spherical shape for it as well. As the neutron number decreases value of β is also increasing, suggesting that these nuclei are deformed. With β>0, it also indicates that these nuclei (^{78}Sr and ^{80}Sr) have a prolate shape rather than a oblate shape.

We also suggest that the ^{82}Sr nuclei might show triaxial deformation. Since the cubic terms were not explicitly included in the Hamiltonian we couldn't get a strong triaxial minima suggesting a O(6) nuclei. Also the theoretically calculated ratio of $E_{3+}/(E_{22+} + E_{21+}) = 1$, which is the limiting value of a triaxial rotor.

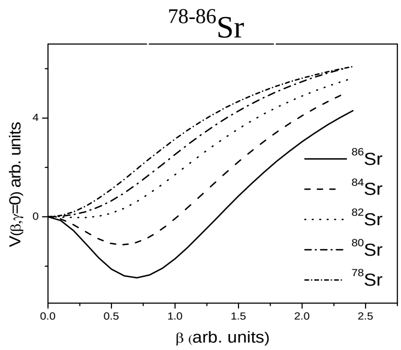

Fig. 2 Plot of $V_{\pi\nu}(\beta, \chi = 0)$ vs β for Sr isotopes.

Summary

We have plotted the PES diagrams for even even isotopes of Sr utilizing the Hamiltonian of IBM - 2 to study the shape transition of these nuclei. It shows a clear transition from that of deformed nuclei to a spherical vibrator as the neutron number increases from 38 to 46.

One of the authors (MS) greatly acknowledges the financial support from CSIR, New Delhi for this research work. She would also like to thank J. B. Gupta and J. Beller for their many fruitful discussions.

References

[1] F. Iachello and A. Arima, Interacting Boson Model, Cambridge University Press ,1987

[2] M. Saxena *et al*, Proceedings of DAE Symp. on Nucl. Phys. , **A 49**, 98 (2010)

[3] Balantekin A.B. *et al*, Phy Lett B **129**,(1983)

[4] Nomura K. *et al* , Phy Rev Lett **101** , 142501 (2008)