IBM – 2 calculations for even - even isotopes of Strontium

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Introduction

Strontium is a transitional nuclei and shows several interesting characteristics. Earlier, IBM 2 has been successfully used to analyze the energy spectra and B(E2) values for the even – even isotopes of Krypton and Selenium.

In this work we have extended the available systematic IBM 2 calculations of Krypton and Selenium region to Strontium region.

Interacting Boson Model – 2

In the Interacting Boson Approximation of Arima and Iachello[1] , the collective excitations of a nucleus are described in terms of s and d bosons with angular momentum L = 0 and 2 respectively. The IBM 2 version distinguishes between neutron (ν) and protons (π) bosons.

In our calculations we have used the following IBM 2 Hamiltonian.

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

where ϵ is the energy splitting between the s and d state and $n_{d\pi}$ are $n_{d\nu}$ the no. of proton and neutron d boson respectively. The second and third term of the Hamiltonian describes the proton – neutron interaction consisting of a quadrupole quadrupole term and a Majorana type exchange force term and κ and λ represent the strength of these two types of forces.. The quadrupole operator is given as

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

The parameter$\chi_{\pi,\nu}$ determines the ratio of the two terms.

In principle, the boson numbers N_{π} and N_{ν} can be treated as parameters, but they are taken to be fixed here, counted as half the number of particles and holes outside of the nearest closed shell. We have considered the Z=28 and 50 as closed shell for this calculation as large quadruple deformations were measured for Z = N = 40 nuclei [2] and therefore no N=40 spherical sub shell closure exists in this region.

Altogether there are five parameters ($\epsilon,\kappa,\chi_{\pi},\chi_{\nu},\lambda$) which are to be adjusted and fitted. A restriction on the parameters of IBM-2 can be achieved by the requirement that χ_{π} depends only on proton and χ_{ν} depends only on neutron number. So we have taken a fixed value for χ_{π} = -1.05 for all the Sr isotopes and χ_{ν} was obtained from systematics [3,4].

Results of the IBM 2 calculation

We have used the computer program NPBOS [5] for our calculations. The parameters used in the calculation are shown in Table I. The experimentally known energy levels are compared with the fitted energy levels in Fig. 2 and are found to be in good agreement.

Table 1: IBM-2 parameters used in the calculation

Nuclei	N_{ν}	ϵ	κ	χ_{ν}	$R_{4/2}$
^{78}Sr	5	0.86	-.24	0.28	3.022
^{80}Sr	4	0.96	-.22	0.49	2.64
^{82}Sr	3	0.99	-.15	0.71	2.33
^{84}Sr	2	1.15	-.15	0.92	2.24
^{86}Sr	1	1.25	-.12	1.14	2.14

The behavior of the ratio of the energies of the first 4^{+} and 2^{+} states serve as a good criterion for the shape transition. The value of $R_{4/2}$ ratio has the limiting value 2 for a quadruple vibrator; 2.5 for non axial gamma soft rotor and 3.3 for an ideally symmetric rotor. As we have seen the calculated values changes from 3 to 2 as we increase the neutron number and also $R_{4/2}$ remains greater than 2 or all the isotopes. It implies that this structure seems to be varying from deformed rotor to very near harmonic vibrator.

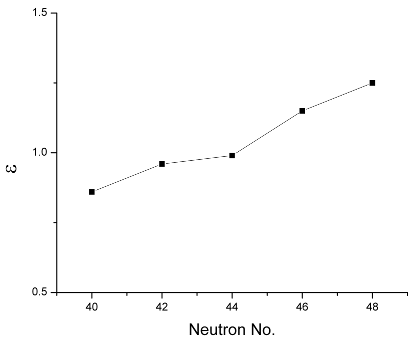

Fig. 1 Variation of ϵ with increasing neutron number

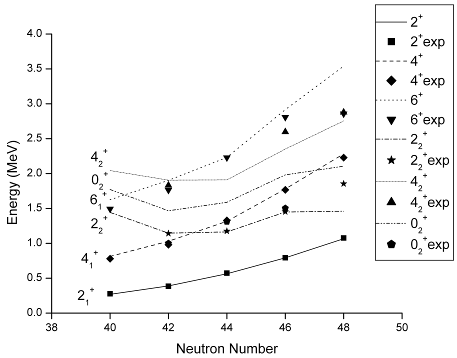

Fig. 2 The calculated IBM-2 energy levels of even - even isotopes of Sr. The dotted lines depict the theoretical values and points show the experimental measured values.

The reduced E2 transition probabilities were also calculated. A common value of the effective charges was considered for all the isotopes. It is very informative to consider the ratio B(E2; $2_2^+ \rightarrow 0_1^+$)/ B(E2; $2_2^+ \rightarrow 2_1^+$) , shown in Fig3, which is 0.7 for SU(3) and 0.011 for SU([6] and also the ratio B(E2; $4_1^+ \rightarrow 2_1^+$)/ B(E2; $2_1^+ \rightarrow 0_1^+$) which is 6 for SU(3) and 1.0 for SU(5). For N>42, the ratio is however is close to its SU(5) value. Since ^{86}Sr is a near spherical nucleus it could not be well fitted using IBM 2. According to these values we can see a transition from SU(3) to SU(5) symmetry as N increases. The energy of the second 2^+ state is higher than the first 4^+ for ^{76,78}Sr and drops for ^{82,84,86}Sr.This behavior for the second 2^+ state is rather typical for the transition from SU(3) to O(6) symmetry.

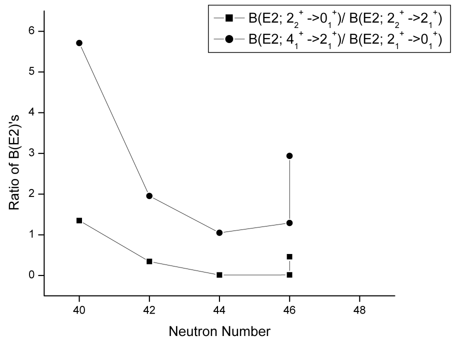

Fig. 3 Theoretical prediction of ratio of B(E2; $2_2^+ \rightarrow 0_1^+$)/ B(E2; $2_2^+ \rightarrow 2_1^+$) and ratio of ratio B(E2; $4_1^+ \rightarrow 2_1^+$)/ B(E2; $2_1^+ \rightarrow 0_1^+$) against the neutron number using IBM 2 calculations .

Summary

IBM 2 provides a good agreement with the available experimental data for the energy levels and transition probabilities. It also shows a strong evidence of transition from SU(3) to SU(5) symmetry when neutron number increases from N=38 to46.

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