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Extension of SU(1,1) *based transitional Hamiltonian in description of intruder levels of* ^{166}*Dy*

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Abstract

In this paper, the SU(1,1) -based transitional Hamiltonians are extended by adding a 2p-2h excitation term to describe some intruder levels of 166Dy nucleus. We used the quantum numbers of U(5) and O(6) dynamical limits to label different levels of this nucleus and control the effect of each symmetry by a control parameter. Our results for $0_2^+, 2_2^+$ and 0_3^+ intruder levels are in satisfactory agreement with experimental counterparts. Also, the results of this extended formalism improve the theoretical predictions for normal states in comparison with non-perturbed Hamiltonian.

Keywords: intruder states, transitional Hamiltonian, particle- hole excitation.

Introduction

The observation of excited state between the levels of ground band , referd to mixing of symmetries. These levels are intruder states and must describe by such formalism which perturbured by some excitation. The IBM Hamiltonian was written from the beginning in second quantization form in terms of the generators of the unitary Lie algebra U(6) The model assumes that low-lying collective excitations of the nucleus can be described in terms of the number N of s and d bosons. The bosons correspond to pairs of nucleons in valance shell, coupled to angular momentum (j=0) s boson (j=2) d boson; N is constant for a given nucleus and equal to half its number of valance nucleons. Lei algebra U(6) subtended by s and d bosons . The model present three special limits that can be solved easily these three limits are *U*(5), *SU*(3) and *O*(6) dynamical symmetry .The study on Dy nucleon report the excitation of 0^+_2,.. levels intruder states these levels are classified as two phonon states where must describe by 2p-2h excitation. [3-7].A method to describe the intruder excitations in the IBM proposed to associate the different shell-model spaces of 0p-0h, 2p-2h,…excitation that two or four protons in the z=50-82 major shell can be excited to next major shell with the corresponding boson spaces comprising N,N+2,… bosons, with N= N_π + N_ν the model Hamiltonian has the form $\hat{H} = \hat{H}_{reg} + \hat{H}_{2p2h}$ where mixes the regular (0p-0h) and (2p-2h) configuration The correlation between valence protons and neutrons is enhanced .due to this cross-shell excitation of protons resulting in the lowering of excited 0^+_2,.. configurations. in this paper we used a U(5)-SO(6) transitional Hamiltonians which are defined in a affine SU(1,1) algebra in IBM1 formalism[1,2]

Theoretical description

The nature of $0_2^+, 2_2^+$ in ^{166}Dy is reported in ref [6] which correspond with SO (6) symmetry. this nucleon ^{166}Dy which is located near the close proton shell has transitional behavior and we extended SU(1,1) Hamiltonian to describe such levels with more Accuracy to this aim we extended Hamiltonian.it is commonly use method which adding a corresponding operator and this adding increase effect of O(6) symmetry on the other hand our SU(1,1) Hamiltonian has a mixing of U(5) and O(6) symmetries.

By employing the generators of SU(1,1) Algebra, the following Hamiltonian is constructed for the transitional region between U(5)↔SO(6)limits[1]

$$H_{extended} = H_{s\hat{u}(1,1)} + H_{so(6)} \quad , H_{s\hat{u}(1,1)} = g\ S_0^+ S_0^- + \varepsilon\ S_1^0 + \gamma\ \hat{C}_2(SO(5)) + \delta\ \hat{C}_2(SO(3)) \qquad (1)$$

g.ε,γ, δ are real parameters where $\hat{C}_2(SO(3))$ and $\hat{C}_2(SO(5))$ denote the Casimir operators of these groups . It can be seen that Hamiltonian would be equivalent with SO(6) Hamiltonian if $C_s=C_d$ and with U(5) Hamiltonian when $c_s = 0\ \&\ c_d \neq 0$. Therefore, the $c_s \neq c_d \neq 0$ requirement just corresponds to the U(5)↔SO(6)transitional region. In our calculation we take C_d(=1) constant value and C_s vary between 0 and C_d

Eigenstates of Extended Hamiltonian (1) can obtain with using the Fourier-Laurent expansion of eigenstates and SU(1,1) generators in terms of unknown $c-$number parameters x_i with $i = 1,2,...,k$. It means, one can consider the eigenstates as

$$\left| k; \nu_s \nu n_\Delta LM \right\rangle = \sum_{n_i \in Z} a_{n_1} a_{n_2} ... a_{n_k} x_1^{n_1} x_2^{n_2} ... x_k^{n_k} S_{n_1}^+ S_{n_2}^+ ... S_{n_k}^+ \left| lw \right\rangle \qquad (2)$$

Eigenvalues of Hamiltonian (1), i.e. $E^{(k)}$, can be expressed[1]

$$\hat{H}_{so(6)} \equiv \hat{C}_2[SO(6)] = h^{(k)} \qquad (3)$$

$$E_{extended}^{(k)} = E^{(k)} + h^{(k)} \quad , \quad E^{(k)} = h^{(k)} + \gamma\nu(\nu+3) + \delta L(L+1) + \alpha\Lambda_1^0$$

$$\Lambda_1^0 = \frac{1}{2}[c_s^2(\nu_s + \frac{1}{2}) + c_d^2(\nu + \frac{5}{2})] \ , \quad h^{(k)} = \sum_{i=1}^{k} \frac{\alpha}{x_i} \qquad (4)$$

We have solved with definite values of c and α for $i = 1$ to determine the roots of Beth-Ansatz equations (BAE) with specified values of ν_s and ν , We carry out this procedure with different values of c and α to provide energy spectra (after inserting γ and δ) with minimum variation as compared to the experimental counterparts;

$$\sigma = \left(\frac{1}{N_{tot}} \sum_{i,tot} \left| E_{exp}(i) - E_{cal}(i) \right|^2\right)^{1/2} \quad (5)$$

which N_{tot} is the number of energy levels ($0_1^+, 2_1^+, 4_1^+, 0_2^+, 2_2^+, 4_2^+$ and *etc*, e.g. 12 levels up to 2_4^+)

Results

Table 1. The parameters of IBM-1 Hamiltonian su(1,1) for ^{166}Dy All quantities (except c_s) are in keV .σ regards as the quality for extraction processes

Cs	δ	γ	α	σ
0.2	-18.80	16.42	500	320
0.3	-18.82	15.97	500	335
0.4	-18.85	15.34	500	343
0.5	-18.89	14.53	500	351
0.6	-18.94	13.54	500	302
0.7	-19.00	12.36	500	312
0.8	-19.07	11.01	500	328
0.9	-19.15	9.74	500	360
1	-19.23	7.76	500	365

Table 2. The parameters of IBM-1 Extended Hamiltonian su(1,1) for ^{166}Dy isotope All quantities (except cs) are in keV.σ regards as the quality for extraction processes

Cs	δ	γ	α	σ
0.2	-8.09	8.70	500	228
0.3	-8.91	8.14	500	232
0.4	-8.92	8.17	500	236
0.5	-8.94	7.76	500	241
0.6	-8.94	7.27	500	249
0.7	-9.00	6.68	500	202
0.8	-9.03	6.00	500	225
0.9	-9.07	5.24	500	229
1	-9.11	4.38	500	238

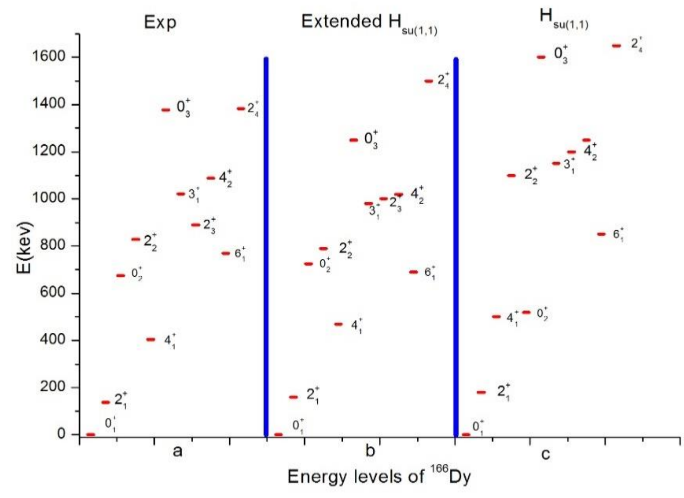

Fig.1.Theoretical predictions based on IBM-1 results of (b) Extended Hamiltonian $SU(1,1)$ for c_s=0.7 (c) the Hamiltonian $SU(1,1)$) for c_s=0.6 for levels of ^{166}Dy isotope in comparison experimental data

we increase c_s from 0.1 to 1 The extractions of the constants(γ, δ) in $SU(1,1)$ Hamiltonian and extended Hamiltonian yield different results ,which our results suggest a minimum values for σ in c_s=0.6 in Table1 and energy levels for this c_s in comparison with experimental data for ^{166}Dy have explained in Fig.1(b) in the recent descriptions of intruder states in ^{166}Dy we have used a Extended Hamiltonian $SU(1,1)$,the parameters of Hamiltonian are presented in Table 2 which suggest more exact results with minimum σ in c_s=0.7 and levels energy have explained in Fig.2(c)

Conclusions

The intruder states of ^{166} Dy nucleus are described by a 2p-2h excitation in the framework of $SU(1,1)$-based transitional Hamiltonian. This nucleus is located in the vicinity of closed shells and show signatures of mixing of several symmetries. We changed the control parameter of this model which describe symmetries mixing, together the excitation term to describe the energy spectra with high accuracy. The results of normal and perturbed Hamiltonians show the advantages of this approach where, for the intruder states $0_2^+, 2_2^+$ and 0_3^+ perturbed one has more exact predictions. Also, the changes in the control parameters of this transitional Hamiltonian verify the superposition of two U(5) and O(6) nature of this nucleus. The better agreement which yield by the extended Hamiltonian suggest the partial symmetry-like structure in this nucleus which is type-II and only, these intruder states belong to this additional symmetry. We would apply this formalism to such nuclei which located near the proton closed-shell to classify such intruder states. Also, these extension will consider for other levels at high energies and high spins.

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