The study of nuclear structure of A=120-200 mass region nuclei in term of symmetry

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Introduction

The study of neutron-deficient light rare isotopes lying far from β-stability line has been of current interest in nuclear structure theory. The phenomenological interacting boson model (IBM) has been widely used for a detailed study of the collective level structure. The model led to the U(6) algebra which yields three dynamical symmetries SU(5), SU(3) and O(6) which corresponds to anharmonic vibrator, deformed rotor and γ-unstable nuclei. Casten symmetry triangle (see figure 1) in its geometric representation describe the three limits.

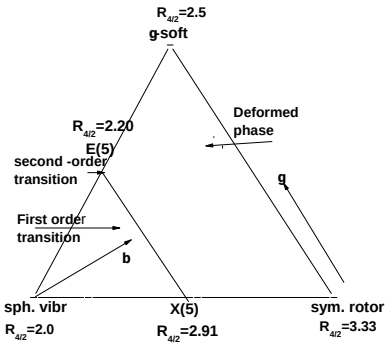

FIG. 1: Casten's symmetry triangle in its geometric representation with the γ-soft O(6) Symmetries (see Ref. [1]).

Each vertex represents a geometric limit and the legs represent the region where the structure undergoes a transition from one limit to other [2]. The nuclei in which neutron and proton are near closed shell can show the SU(5) behavior while neutron and proton near the mid shell would suggest SU(3) behavior. The occurance of O(6) symmetry is expected in cases where neutrons are particle and proton as holes, or vice versa. In the present work we compare the experimental energy with the calculated O(6) energy and also study the shape phase transition.

Calculation

The interacting boson hamiltonian have the form

$$H = e_0 + e_1 b_1(U6) + e_2 b_2(U6) + \epsilon b_1(U5) + \alpha b_2(U5) + \beta b_2(O5) + \gamma_2(O3) + \delta b_2(SU3) + \eta b_2(O6) \quad (1)$$

The analytic solutions can be obtained whenever the Hamiltonian can be written in terms only of Casimir operators of one chain. Its eigen values can be found by analyzing the eigenvalues of the corresponding Casimir invariants. Three chains symmetries are

$$U(6) \longrightarrow \begin{cases} U(5) \supset O(5) \supset O(3) \supset O(2) & (I) \\ SU(3) \supset O(3) \supset O(2) & (II) \\ O(6) \supset O(5) \supset O(3) \supset O(2) & (III) \end{cases}$$

One can show that the three subalgebras I, II and III are only possible ones if one wants to include the rotation algebra, O(3), as a subalgebra. In fact, starting from U(6) one has considered U(5), U(3) and O(6). Representations of the groups appearing in chain I are characterized by the following quantum numbers

$$\left| \begin{array}{ccccc} U(6) \supset & U(5) \supset & O(5) \supset & O(3) \supset & O(2) \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ [N], & n_d, & \nu, \check{n}_\Delta, & L, & M_L \end{array} \right\rangle$$

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Representations of the groups appearing in chain II are characterized by the following quantum numbers

$$\left| \begin{array}{cccc} U(6) \supset & SU(3) \supset & O(3) \supset & O(2) \\ \downarrow & \downarrow & \downarrow & \downarrow \\ [N], & (\lambda,\mu), \widetilde{\chi}, & L, & M_L \end{array} \right\rangle$$

Representations of the groups appearing in chain III are characterized by the following quantum numbers

$$\left| \begin{array}{ccccc} U(6) \supset & O(6) \supset & O(5) \supset & O(3) \supset & O(2) \\ \downarrow & \downarrow & \downarrow & \downarrow & \downarrow \\ [N], & \sigma, & \tau, \nu_\Delta, & L, & M_L \end{array} \right\rangle$$

The analytic solution can be obtained whenever the Hamiltonian can be written in terms of Casmir operators of one chain. For O(6) nuclei Hamiltonian is

$$H = e_0 + e_1 b_1(U6) + e_2 b_2(U6) + \beta b_2(O5) \quad (2)$$

Thus the Hamiltonian is diagonal in the basis eq. (2) with eigenvalues

$$E\left([N]\tilde{v}_\triangle \sigma\tau LM\right) = A\frac{1}{4}(N-\sigma)(N+\sigma+4) + B\frac{1}{6}\tau(\tau+3) + CL(L+1) \quad (3)$$

The quantities A, B and C are constants and L be the quantum number. For low lying group of levels, with is equal to N the first term equal to zero. The effect of C-term is also monotonic in breaking the degeneracy's of each τ-multiplet therefore at C=0 the energy spacing are given by the B-term, deformed γ-unstable oscillator which is the closest counterpart to the O(6) limit [3].

Result and Discussion

By putting the value of N,σ,τ and L in eq.(3) we calculated the value of B and C for which experimental data are taken from Sakai [4] and [5] as follows. The theoretical energy is also calculated from the eq.(3). A few data of experimental and theoretical energy values are presented in Table 1.

TABLE I: Comparison of ground state band energies of few nuclei, (all in MeV).

Isotopes	Energy	2^+	4^+	6^+	8^+	10^+
^{120}Xe	Exp	0.322	0.795	1.396	2.047	2.871
	O(6)	0.322	0.767	1.334	2.023	2.835
^{122}Xe	Exp	0.330	0.827	1.466	2.216	3.038
	O(6)	0.330	0.818	1.463	2.264	3.222
^{124}Xe	Exp.	0.354	0.878	1.548	2.330	3.170
	O(6)	0.354	0.905	1.655	2.603	3.748
^{130}Ba	Exp.	0.357	0.901	1.592	2.394	3.259
	O(6)	0.357	0.885	1.585	2.455	3.496
^{132}Ba	Exp.	0.464	1.127	1.932	2.796	
	O(6)	0.325	0.810	1.453	2.255	3.215
^{132}Ce	Exp.	0.325	0.857	1.540	2.326	3.154
	O(6)	26.44	0.14	7.65	14.28	0.13
^{138}Nd	Exp.	0.520	1.249	2.134	3.105	3.171
	O(6)	0.520	1.462	2.824	3.312	4.025
^{196}Pt	Exp.	0.356	0.877	1.527	2.255	3.045
	O(6)	0.356	1.001	1.935	2.963	3.158

Conclusion

There are many nuclei in the Xe, Ba, and Ce region described in terms of γ- soft rotational nuclei [6]. The ^{128}Xe is the new example of the E(5) symmetry. The $^{186-188}$Pt shows the O(6) symmetry. We observe that the energy calculated by O(6) symmetry shows close agreement with the experimental energy.

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