CONF-8405231--7

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DE85 001895

PARTICLE-CORE COUPLING CALCULATIONS FOR THE POSITIVE PARITY STATES IN THE ODD-MASS HG ISOTOPES AS A TEST OF IBA CORE DESCRIPTIONS

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ABSTRACT

IBM2 with mixing between different boson numbers

A particle-core coupling calculation has been made for the positive parity states in the odd-mass Hg isotopes, A = 187 to 197. This work employed the results of recent "~~IBA mix~~" calculations to describe the even-mass Hg cores. ~~The coupling parameters are fixed in a simple way, and~~ a comparison between the calculated results and the experimental level scheme can be interpreted as a test of the core description.

1. Introduction

The Hg isotopes have been a long-standing challenge to theoretical interpretation. The experimental systematics of the first few excited states in the even-mass Hg isotopes, A = 186 to 198, are well-known. Two features of these isotopes are particularly striking, namely, (1) the remarkable apparent structural regularity of the heavier isotopes (A ≥ 190) and (2) the appearance of an extra band of states in the lighter isotopes (A ≥ 188). This extra band of states has generally been interpreted1) as a rotational band built upon a deformed shape which coexists with the weakly oblate structure found in the heavier Hg isotopes. Whether this deformed shape is prolate or oblate is an open question, and in fact, it is not certain if the ground-state band in the light isotopes (A ~ 186) is built upon the same weakly oblate structure found in the heavier isotopes. Early potential energy surface calculations2) clearly showed an oblate shape for the ground band and a prolate shape for the intruder band, but a more recent analysis3) of experimental B(E2) ratios (comparing intraband to interband E2 transitions) clearly favors the same sign of deformation for the intruder and ground-state bands, i.e., either both oblate or both prolate. To date, there has been only one attempt at a detailed calculation[4] for a wide range of Hg isotopes, in which the intruder band is interpreted as due to a proton pair excitation across the Z = 82 shell gap. This leads to an increase in valence proton pairs (bosons) from 1 boson (hole pair) for the regular states to 3 bosons (2 hole pairs + 1 particle pair) for the intruder states. The regular and intruder states are each treated separately in a standard IBA-2 calculation (neutrons M and protons being distinguished) and the resulting states are allowed to mix for each even-mass Hg isotope. These calculations are the most extensive (~~and probably the most sophisticated~~) in this so far region. Good agreement was obtained with the enrgy spectdra in e both heavy and light isotopes, but one rather surprising result was the predicted change of sign in the quadrupole moment of the first 2 + state signaling a change from oblate to prolate in the ground- 2^+ state band.

This change should be reflected in the structure of the neighboring odd-A nuclei, and at the least these even-mass calculations must be consistent with experimental data in the odd-A nuclei. Therefore, one test of the validity of the IBA cores is to M use those results as input for a particle-core coupling calculation for the relevant odd-A bands. This procedure directly exploits the ability of the odd particle to act as a probe of the core. The particle-core coupling model used in this work is discussed more extensively elsewhere in these proceedings[5] and so only a brief description is given below.

2. Outline of the Model

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The model of Ref. 6 gives a quivte general approach for describing collective states in odd-A nuclei as a coupling between a single-particle state and the collective states of the $A \pm 1$ even-even cores. The Hamiltonian is written in the form

$$H = H_{sp} + H_{cores} + \kappa q \cdot Q + H_{pair} \qquad (1)$$

where H_{sp} is the Hamiltonian for the odd particle in its spherical mean field and H_{cores} denotes the core Hamiltonian (described more H. of the [illegible] even neighbor completely below). The actual particle-to-core coupling is achieved in the q·Q term, where q and Q refer to the quadrupole operators of the particle and the core, respectively. The pairing part of the Hamiltonian, H_{pair}, is treated in the ~~standard~~ BCS approximation ~~method~~ and controls the particle-hole nature of the wavefunction.

The wave function for an odd-A state with total angular momentum I is written in the form

$$|I,A\rangle = \Sigma \{u_I(jR)[a_j^+|R,A-1\rangle]_I + V_I(jR)[a_j|R,A+1\rangle]_I\} \quad (2)$$

small v

where the first term represents a particle in a spherical j-orbital coupling to the collective state R of the A-1 core, while the second term represents the coupling of a hole to the A+1 core. This is a spherical basis, but with the particle and hole amplitudes u and v explicitly noted. By using core states of good angular momentum R, one can require that they be eigenstates of the core Hamiltonian, and therefore only the eigenvalues of the core are required.

These numbers, along with the reduced matrix elements of the quadrupole operator between all core states are sufficient to characterize the A ± 1 cores completely. In this way, one can do a calculation for the cores separately and use the results directly as input for odd-A calculations.

3. Results and Discussion

For simplicity, we chose to consider the unique (positive) parity states in the odd-A Hg isotopes (A = 187 to 197) for which extensive experimental data are available[7], and which can be well-approximated as a single j-shell (neutron $i_{13/2}$) coupling to the even-even cores. Within this framework, there are only three parameters to be determined: the Fermi energy λ, the q·Q coupling strength κ, and the pairing energy Δ. For each odd-mass isotope, the pairing gap Δ is determined from odd-even mass differences. The parameter κ was fixed to reproduce the energy of the 17/2+ (j+2) state in ^{197}Hg. This value is then kept fixed for all calculations. This leaves the Fermi energy as the only free parameter, which is fixed to reproduce the energy of the 11/2+ (j - 1) state in each nucleus. The results of these calculations for ^{197}Hg are compared with experiment and with the calculations of Ref. 8 as shown in Fig. 1. (All energies are measured relative to the 13/2+ state.) Clearly, the agreement is quite good. The calculations for A = 195 to 189 are summarized in Fig. 2 and again the agreement is quite good. Perhaps more importantly, the quality of the fits do not degrade with decreasing A, suggesting at least that the odd-A Hg isotopies considered so far are not inconsistent with the IBA cores.

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The calculations for the critical case, ^{187}Hg, are shown in Fig. 3. The most important aspect of the experimental spectrum is the appearance of the strongly coupled (ΔI = 1) band sequence beginning with the j = 9/2 bandhead at 166 keV[9]. This strongly coupled band ~~could~~ not ~~be~~ reproduced in this calculation, which suggests that the particle coupling to the core intruder band is not strong enough for some reason. One possibility is that the

was not well

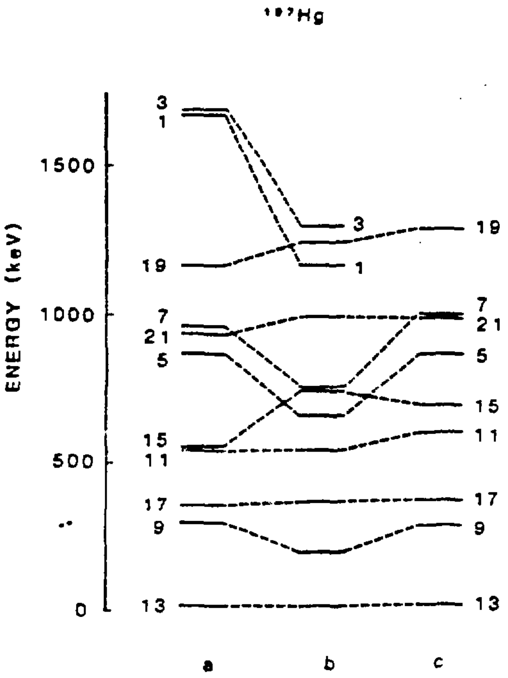

Fig. 1 Comparison between this calculation (a) with experiment (b) and the calculation of Ref. 8 (c). The states are labeled with twice their spin, and only the first state of each spin is shown. The strength of the q·Q interaction and the Fermi energy were fixed to reproduce the energies of the 17/2 and 11/2 states, respectively.

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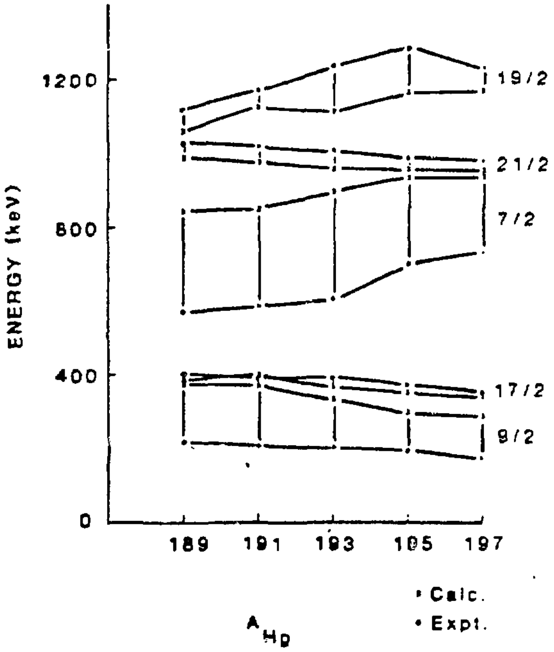

Fig. 2 A systematic comparison between this calculation and experiment for those states found in A = 189 thru 197. The 11/2 state is not shown because the Fermi energy is fixed to reproduce the energy of this state in each nucleus. The q·Q interaction strength is fixed to reproduce the energy of the 17/2 state only in A = 197, and is held constant elsewhere.

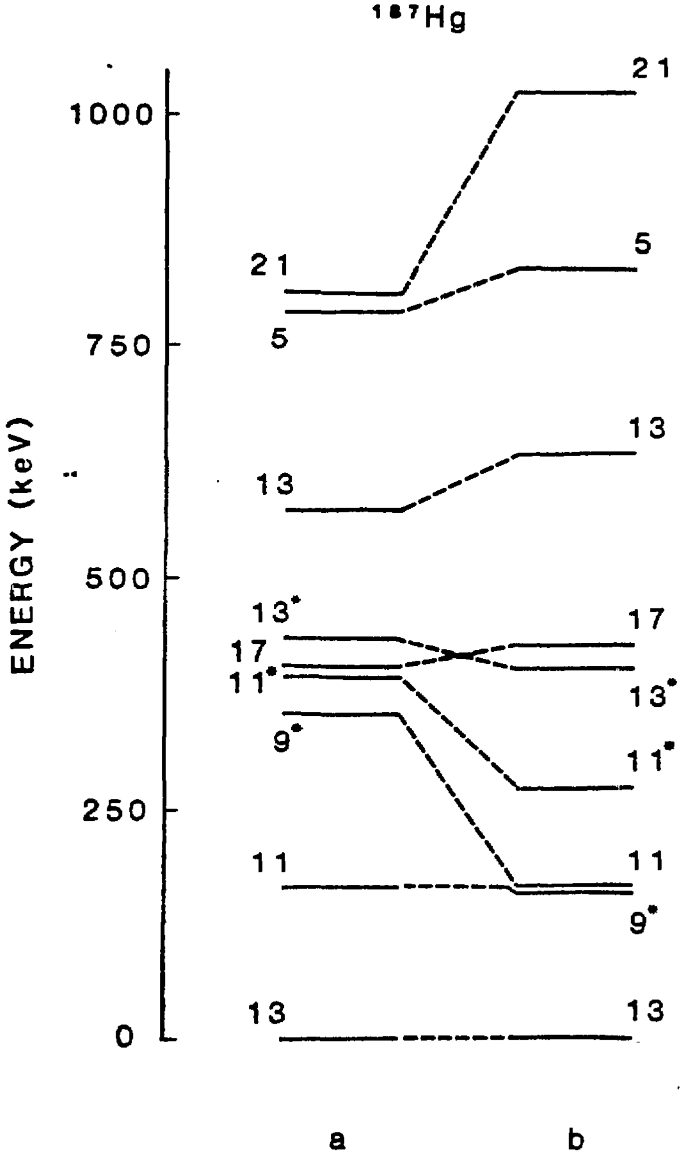

Fig. 3 Comparison between this calculation (a) and experiment (b). The states are labeled with twice their spin, and the asterisks mark the members of the strongly coupled band.

as in recent IBFM2 calcs! Sch.)

[illegible] is [illegible], the odd neutron should couple mainly to the core [illegible] moment, which shows a [illegible] from the ground to the intruder band than the total [illegible].

core quadrupole matrix elements for the intruder band are too small by a factor of ~ 2.5. A comparison of experimental and theoretical (E2) values for $^{184, 186}$Hg is not conclusive in this regard[4]. B

Regard on the ground band ~~Finally,~~ the above calculations have shown ~~only~~ that the IBA cores can provide a sufficient but perhaps not a necessary description of the even mass Hg isotopes. (Pre~~liminary~~) calculations using a single core (^{198}Hg) for the odd isotopes A = 189 to 197 and varying only λ have not produced results significantly different from those presented above. This suggests that the changing Fermi energy may be masking the effects of the changing quadrupole field in the IBA cores, and therefore the question of whether the quadrupole moment of the first 2+ state of the even-mass Hg isotopes changes sign cannot yet be considered fully resolved. M V M

This work was supported in part by the U.S. Department of Energy under Contract Nos. DE-AS05-76ER0-3346(P.B.S.), DE-AC05-76OR00033 (G.A.L.) and DE-A505-80ER10599(J.L.W.).

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