DEFORMATION PROPERTIES OF EVEN-EVEN Os, Pt, Hg NUCLEI AND SPECTROSCOPIC PROPERTIES OF ODD Re, Os, Ir, Pt, Au, Hg NUCLEI FROM SELF-CONSISTENT CALCULATIONS

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Abstract

Static properties of even-even Os, Pt, Hg nuclei have been obtained from HF + BCS calculations. Single-particle wave functions which come from these self-consistent calculations have been used to calculate some spectroscopic properties of odd Re, Os, Ir, Pt, Au and Hg nuclei, within the rotor + quasiparticle coupling model. Our calculations are able to give a good description of most of available experimental data.

1. Introduction

The Re, Os, Ir, Pt, Au and Hg nuclei belong to a transitional region of the nuclide chart. Numerous experimental and theoretical studies have been already devoted to these nuclei. The coexistence of oblate and prolate nuclear shapes which is found in all calculations, may explain most of experimental results concerning these transitional nuclei. In the present work we have performed an extensive self-consistent study of this nuclear region. The static properties of 17 even-even Os, Pt, Hg nuclei have been determined. From these calculations we have extracted quasi-particle states to estimate spectroscopic properties of many odd nuclei within a rotor + quasiparticle coupling approximation. So far we have restricted our study to axially symetrical solutions.

2. Deformation properties of even-even Os, Pt and Hg nuclei

Assuming axial symmetry and using the Skyrme phenomenological effective force SIII, HF + BCS calculations [1)] have been performed for the ^{180,184,186,190,192,200}Hg, ^{182,184,186,188,190,192,196}Pt and ^{184,188,192,196}Os nuclei [2)]. Potential energy curves exhibit two minima for most of these nuclei. Static properties (masses, charge radii r_c, deformation parameters β_2...) of the equilibrium solutions so obtained, are in good agreement with available experimental data. It is interesting to note that the coexistence phenomena which explains most of experimental data is well reproduced by our calculations. As an example fig.1 shows the variation of the calculated charge radii of Hg isotopes against the neutron number for the oblate ($\beta_2 < 0$) and prolate ($\beta_2 > 0$) equilibrium solutions as well as for the constrained spherical solution ($\beta_2 = 0$) The differences between prolate and oblate r_c values in ^{184,186}Hg are in excellent agreement with experimental results obtained by isotopic shift measurements [3)] if shape coexistence is assumed.

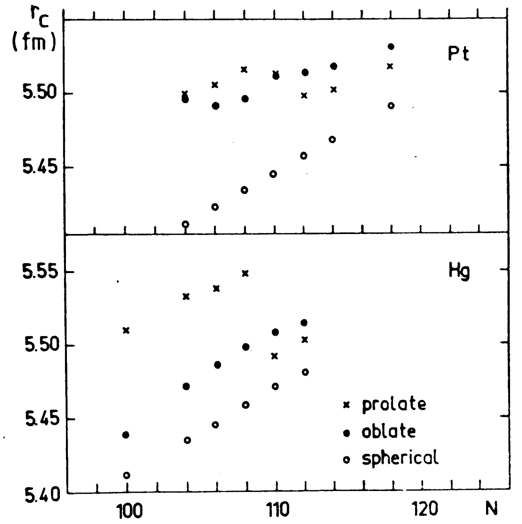

Fig. 1 : Variation of Mercury, Platinum isotope charge radii versus neutron number for oblate and prolate HF solutions and for constrained spherical solutions.

3. Spectroscopic properties of odd Re, Os, Ir, Pt, Hg nuclei

3.1 A brief survey of the method

We have evaluated the spectroscopic properties of odd-A nuclei within a rotating core + quasi particle coupling model [4)]. The quasi-particle energies and wave functions in use come from axially symmetrical equilibrium HF + BCS calculations and are thus determined in a self-consistent way. The standard unified model wave functions for odd nuclei have been expanded onto good core angular momentum R states. This has allowed us to introduce the core variable moment of inertia extracted from core experimental energies. Furthermore we have included all quasiparticle states whose HF energies belong to a ±5 MeV energy interval around the Fermi level. Finally we stress that there is no adjustable parameter in our calculations (as e.g. attenuation factor). This model has already been applied with success to transitional nuclei (Cd, Er with $\beta_2 \sim 0.15$), to deformed nuclei (actinide region with $\beta_2 \sim 0.3$) and even to fission isomers (with $\beta_2 \sim 0.6$) [4)].

3.2 Results : Spectroscopic calculations have been performed for odd Re, Os, Ir, Pt, Au, Hg nuclei. In what follows we shall only give some examples of our results.

3.2.1. Odd neutron nuclei results

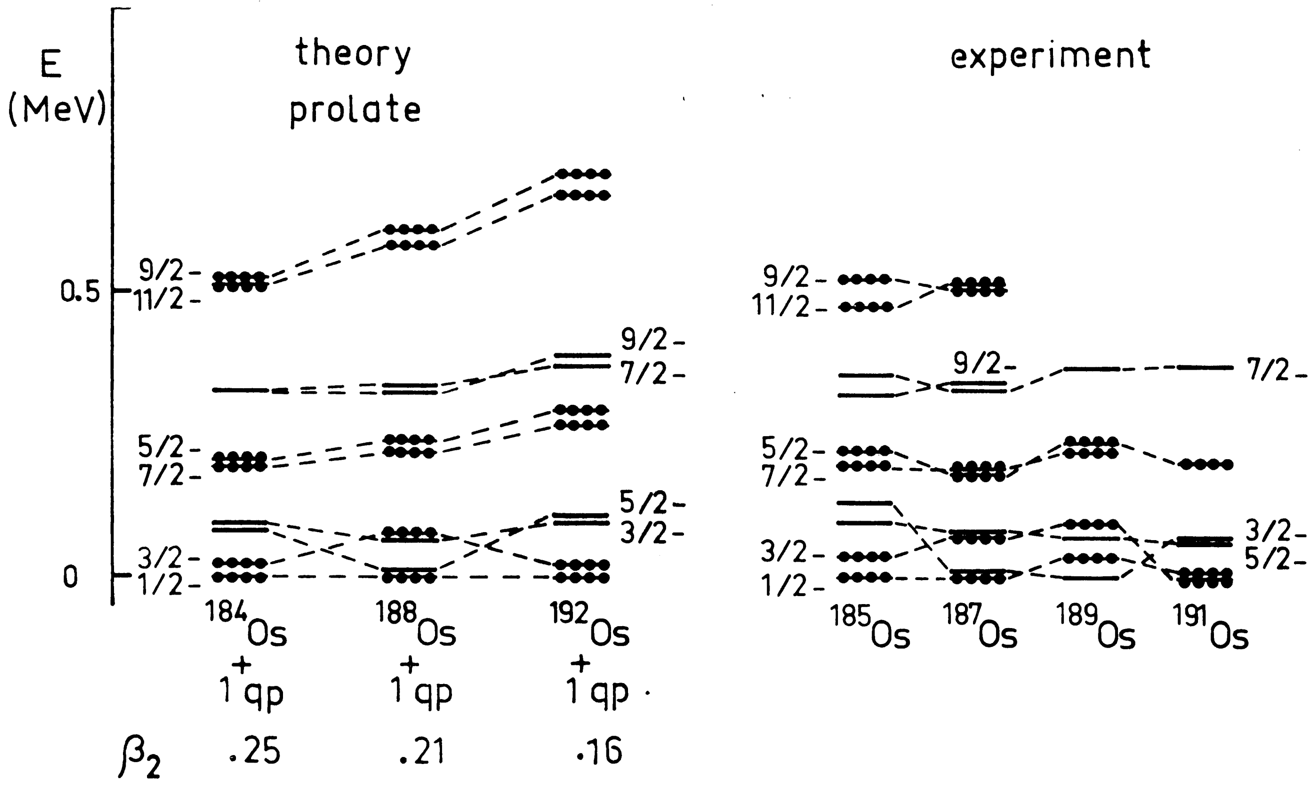

Fig. 2 : Theoretical and experimental evolution of $1/2^-$ *and* $3/2^-$ *band states along the Os isotopic series* (____ $1/2^-$ *band*, ●●● $3/2^-$ *band*).

The ^{185,187,189,191,193}Os nuclei have been extensively studied $^{5,6)}$ by (p,t ; α, 2nγ; n,γ ; ...) reactions. Quasi-rotational bands built on $1/2^-$ and $3/2^-$ states have been found over the whole isotopic series. As shown on fig. 2 our calculations are able to very well reproduce these experimental data for Os prolate shaped nuclei. The wave functions of $1/2^-$ and $3/2^-$ band states are very much mixed (cf table 1) and therefore we have more or less arbitrarily performed the band assignment in terms of the major quasiparticle component.

A decoupled band built on the 1i13/2 level has been observed in ^{187}Pt and a $\Delta I = 1$ band has been found in ^{185}Pt $^{7)}$. In order to represent the ^{185}Pt nucleus, calculations have been performed from both ^{184}Pt and ^{186}Pt cores for both oblate and prolate solutions. If we compare the experimental $\Delta I = 1$ band in ^{185}Pt with prolate ^{184}Pt or ^{186}Pt core calculations we find that they nicely agree as shown on fig. 3. We also confirm the ground state spin which was assumed to be 9/2 from disintegration properties $^{8)}$. On the contrary the data seem incompatible with the results of oblate ^{184}Pt or ^{186}Pt core calculations exhibiting a strongly Coriolis mixed or even (for the ^{186}Pt core) decoupled character. The calculations performed with oblate ^{186}Pt or ^{188} Pt core are in qualitative agreement with the observed decoupled band in ^{187}Pt (see fig. 3).

Such decoupled bands built on $13/2^+$ states corresponding to oblate shaped nuclei are also observed in the mercury nuclei $^{9,10,11)}$. When the nucleon number decreases,

TABLE 1 :

Wave function percentages of the $1/2^-$ and $3/2^-$ band states mixed by the Coriolis force ;
A and B are Hartree-Fock + BCS states of ^{188}Os core, their wave functions are expanded on the usual asymptotic basis.

	A	B
$1/2^-$	100.0	
$3/2^-$	52.8	45.3
$5/2^-$	59.8	40.0
$7/2^-$	50.4	49.2
$9/2^-$	57.1	42.3
$3/2^-$	45.5	54.4
$5/2^-$	39.6	59.2
$7/2^-$	47.9	49.4
$9/2^-$	41.1	55.4

$$A = 34\%\ \{1/2^-[510]\} + 19\%\ \{1/2^-[710]\} + 18\%\ \{1/2^-[310]\} + 10\%\ \{1/2^-[730]\}\ .$$

$$B = 43\%\ \{3/2^-[512]\} + 17\%\ \{3/2^-[712]\} + 13\%\ \{3/2^-[312]\} + 9\%\ \{3/2^-[732]\}\ .$$

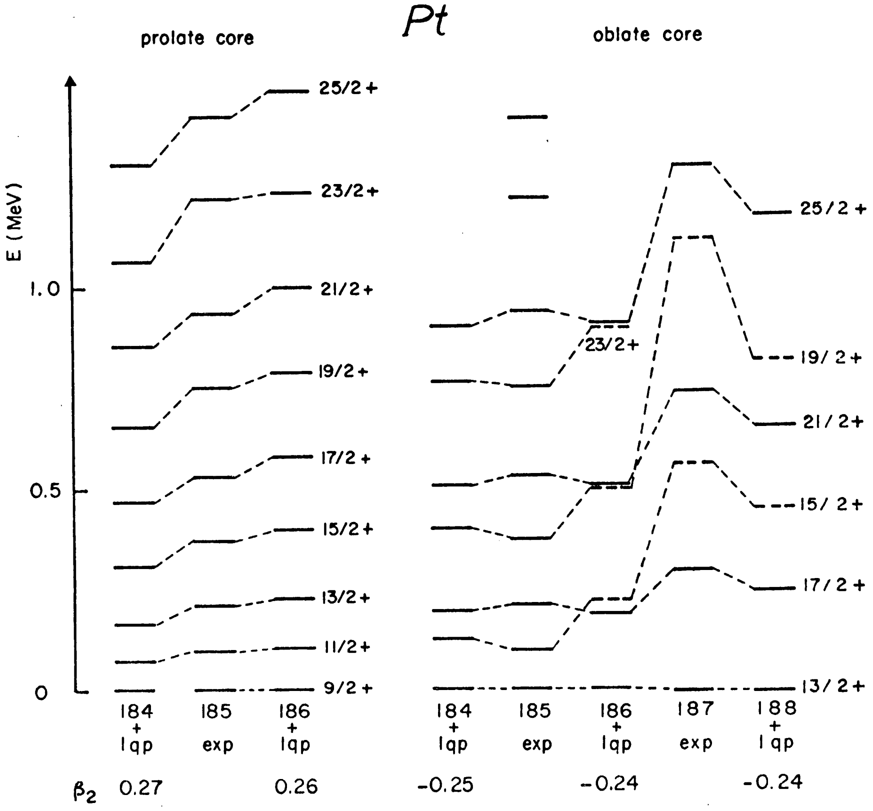

Fig. 3 : High spin states of the ^{185}Pt nucleus compared to the calculated states from ^{184}Pt core and from ^{186}Pt core both for oblate and prolate HF solutions. For oblate core calculations we have also reported ^{188}Pt core results in comparison with ^{187}Pt experimental data. Only theoretical yrast states (which are the only ones experimentally known) have been plotted.

$15/2^+$ and $13/2^+$ state energies decrease whereas $17/2^+$ and $21/2^+$ state energies increase. This calculated trend comes from of the penetration of the Fermi level inside the 1i13/2 shell as shown on fig. 4 and is consistent with the experimental evolution of the high spin bands of the mercury isotopes.

3.2.2. Odd-proton nuclei results

In addition to a decoupled $9/2^-$ band and a normal $11/2^-$ band corresponding to a prolate shaped nucleus, two low spin bands ($1/2^+$ and $3/2^+$) have been observed in Ir isotopes [8]. A comparison between theoretical results and experimental data shows that the $1/2^+$ band corresponds to an oblate intrinsic shape for the ^{185}Ir nucleus and seems to correspond to a prolate intrinsic shape for ^{183}Re [5] (fig. 5). For the decoupled $9/2^-$ band which comes from the 1h9/2 shell, our calculations are able to reproduce rather nicely all states up to 1 MeV for ^{185}Ir when calculated with a prolate shaped core (fig. 6).

The comparison of recent experimental results concerning the lowest energy states of ^{185}Au with our calculated results shows that some states due to 3p3/2 + 2f7/2 shells exists at an excitation energy of about 200 keV (fig. 7). These last results are discussed more completely in another contribution to this conference [12].

4. Conclusions

Available static properties of even-even nuclei have been well reproduced by means of HF + BCS calculations performed with the Skyrme SIII effective force. Furthermore in spite of the restrictive axial symetry hypothesis and the absence of any adjustable ad hoc parameter, the rotating core + quasi particle coupling model using single-particle wave functions determined in a self-consistent way, is able to represent the set of available experimental data better than expected for the slightly deformed nuclei under consideration here.

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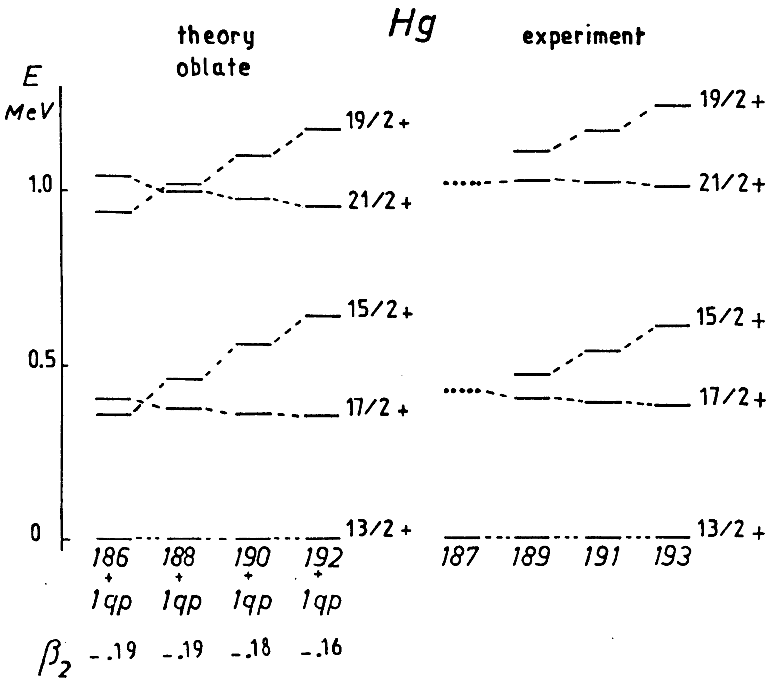

Fig. 4 :

Theoretical and experimental evolution of high spin states (I > 13/2) for some neutron deficient Mercury isotopes.

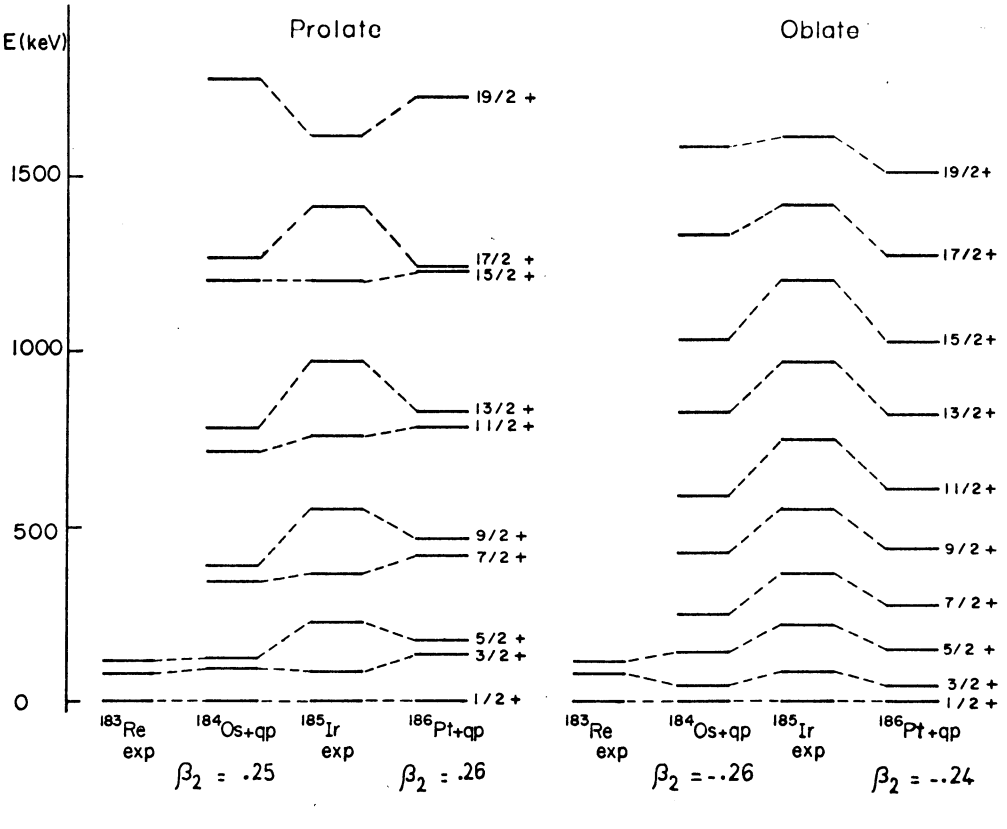

Fig. 5 : Comparison of 1/2$^+$ band states in ^{185}Ir and ^{183}Re with those calculated from ^{184}Os and ^{186}Pt core for prolate and oblate HF solutions.

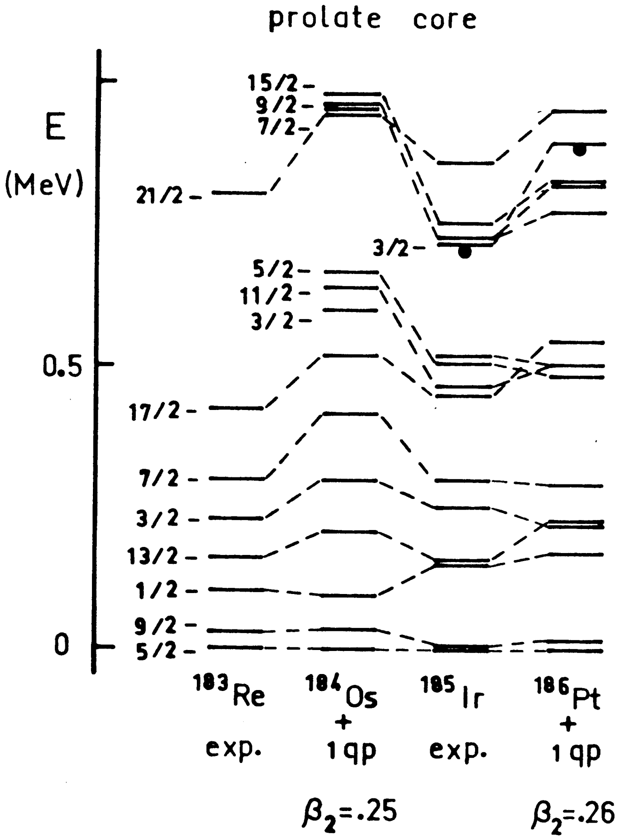

Fig. 6 : The 9/2⁻ band arising from the h9/2 shell in ^{183}*Re and* ^{185}*Ir compared to the calculated bands from* ^{184}*Os and* ^{186}*Pt core for a prolate HF solution.*

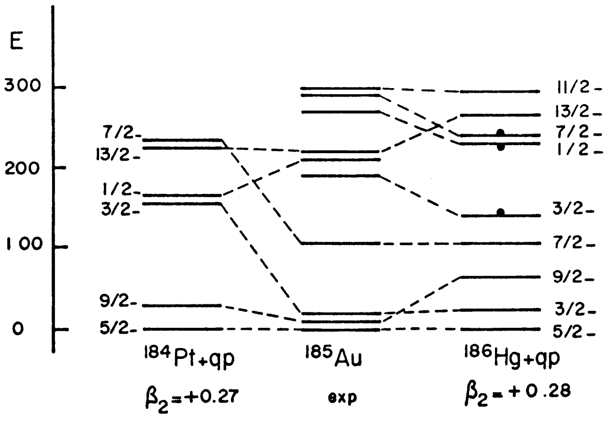

Fig. 7 : Comparison of experimental results concerning lowest energy states of ^{185}*Au and theoretical results obtained from* ^{184}*Pt and* ^{186}*Hg prolate core (—— states which come from h9/2 (∿65%) + f5/2 (∿25%), —●— states from p3/2 (∿40%) + f7/2 (∿30%) + h11/2 (∿10%)).*

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