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PROPOSAL TO THE ISOLDE COMMITTEE

γ-VIBRATIONAL BANDS IN ^{186}Hg

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SUMMARY : Shape coexistence in Hg nuclei with A ≤ 188 has been clearly suggested by experimental data. In ^{186}Hg, two rotational bands have been observed : the ground state band corresponding to a weakly deformed nucleus and the excited band built on the first 0^+ excited state corresponding to a well-deformed prolate nucleus. Recent microscopic calculations reproduce these results and also predict a γ-vibrational band and a β-vibrational band for each of the deformations. For the first time, a shape coexistence of γ-vibrational and β-vibrational bands has been predicted. Some hints of the existence of these γ-vibrational bands have been found in existing data. We propose to : i) search for other states of these γ-vibrational bands in Hg and ii) to determine spin and parity values of the levels populated in the β^+/EC decay of ^{186}Tl. The beam time needed is 15 shifts.

γ-VIBRATIONAL BANDS IN ^{186}Hg

I - INTRODUCTION

Shape coexistence in $^{185,186}Hg$ isotopes was suggested by experimental results a long time ago [1,2]. Very recently, microscopic calculations have been performed in neutron-deficient Hg nuclei [3]. In addition to reproducing the shape coexistence already suggested by the experimental results, they predict two rotational bands built on γ-vibrational states with each of the bands corresponding to one of the nuclear shapes. Thus, for the first time, theory predicts shape coexistence not only for K = 0 bands but also for K = 2, γ-vibrational bands and K = 0, β-vibrational bands. From results of an experiment on ^{186}Hg performed with another aim, some states of these γ-vibrational bands have been tentatively identified [3]. We propose here to perform an experiment to : i) search for the other states of these γ-vibrational bands and eventually states of β-vibrational bands and ii) determine the parity values and to limit the number of possible spin values of the levels observed in the β^+/EC decay of ^{186}Tl.

II - INFORMATION ALREADY KNOWN ON ^{186}Hg

1) Shape coexistence in ^{186}Hg

Two rotational bands have been observed in ^{186}Hg, the first one built on the ground state and the second on a 0^+ excited state located at low excitation energy. The moments of inertia of these two bands are very different. That of the ground state band indicates a small deformation ($\beta_2 \sim 0.14$) of the nucleus whereas that of the excited band indicates a larger deformation ($\beta_2 \sim 0.26$) [1]. The charge radius change between A = 186 and A = 185, determined from isotopic shift measurements [2], was interpreted as a transition from a quasi-spherical shape for ^{186}Hg, to a well-deformed prolate shape for ^{185}Hg. The resulting difference of deformation between the ^{186}Hg and ^{185}Hg ground states is quite similar to that observed for the two bands in ^{186}Hg.

Therefore, a shape coexistence was clearly observed in ^{186}Hg.

2) Theoretical predictions

Numerous theoretical computations have been performed and the potential energy surfaces obtained using the various approaches are rather smooth. More recently, microscopic calculations were performed in ^{186}Hg to search for collective states due to

γ-vibration and β-vibration, [3]. The Bohr-like quadrupole-collective Hamiltonian is built microscopically [4] and the collective masses and the moment of inertia entering the Hamiltonian are determined using the Hartree-Fock-Bogoliubov theory and the Gogny force [5]. The potential energy surface obtained for ^{186}Hg is smooth but has two minima. Besides these two minima, two rotational bands built on 0^+ states are predicted : a weakly deformed band and a clearly deformed band. The other collective states that are predicted at low excitation energy have been organized in several bands from the reduced transition probabilities as shown in fig.1a. Two of these bands (2^+, 3^+, 4^+, 5^+, 6^+ sequences) look like γ-vibrational bands. The one on the left can be associated with the deformed band and the other with the weakly deformed band. There are two other bands that look like β-vibrational bands, each related to one of the coexisting bands [3] (see fig.1a).

Thus, γ- and β-vibrational bands are predicted to exist in Hg nuclei like in Pt and Os isotopes. Furthermore, a shape coexistence is also predicted for γ- and β-vibrational bands.

3) Experimental results

When the theoretical calculations described above were completed, we had just performed angular correlation measurements of ^{186}Hg at ISOCELE in order to determine the mixing ratio of E2 and M1 multipolarities in the $2_2^+ \rightarrow 2_1^+$ transition. Although the aim of this experiment was not to observe the predicted γ-and β-vibrational bands, we have searched for them through the existing data.

A 2^+ level located at 1096.4 keV has been clearly identified as the 2^+ γ-vibrational state associated to the deformed band (see fig. 1b). From the relative reduced transition probabilities three other levels are tentatively identified as the 3^+, 5^+ and 7^+ states of the deformed γ band. Moreover, there are two other levels that could correspond to the 2^+ and 3^+ states of the weakly deformed γ-vibrational band [3] (see fig.1b ; the 7^+ is not shown). It is worth noting that the parity and spin values of the identified levels are not uniquely determined except for the 1096.4 keV level. Moreover, no candidates could be found for the 4^+ and 6^+ levels of the first γ - vibrational band (see fig.1).

III - PROPOSED EXPERIMENT

In order to find the missing levels, to determine the parity values and to limit the number of possible spin values of the levels observed in the β^+/EC decay of ^{186}Tl, we propose to perform e-γ and γ-γ coincidence measurements with a γ energy range up to 4.5 MeV. For nuclei far from stability in this mass region the β^+/EC decay usually feeds several states located at rather high energies. These states, very likely quasiparticle states, several states located at rather high energies. These states, very likely quasiparticle states, de-excite towards many levels. Since several states located at energies smaller than 2.2 MeV have known spin and parity values (e.g. 0^+, 2^+, 4^+, 6^+, 8^+, 10^+, 8^-) it is easy to determine the spin and parity values of states which decay towards some of them especially when the transition multipolarities are also measured by electron detection.

The γ-γ coincidence measurements will be performed using three Ge(HP) detectors 70% efficiency.

The e^--γ coincidence measurements will be performed using a Ge(HP) 70% efficiency γ detector and a cooled Si(Li) detector coupled to a mini-orange spectrometer to preserve the electron detector from the β^+, X-rays and γ-rays emitted by the radioactive source.

In these experiments, lead plus copper will shield the γ detectors against background and compton scattering of the γ-rays in surrounding materials.

IV - BEAM TIME REQUEST

The feeding of γ-vibrational bands is estimated to be around 0.5 %. We estimate 20 times more coincidence events than at ISOCELE by use of high-efficiency γ detectors placed close to the radioactive sources. In these conditions and using a ^{186}Tl yield of 2.7 10^4 atoms/s. The estimated beam time required is :

– 9 shifts to locate γ transitions with intensities as weak as 0.1% in the level scheme (γ-γ coincidence measurement)

– 6 shifts to determine the multipolarity of the transitions (e^--γ coincidence measurement).

In total the beam time request is 15 shifts.

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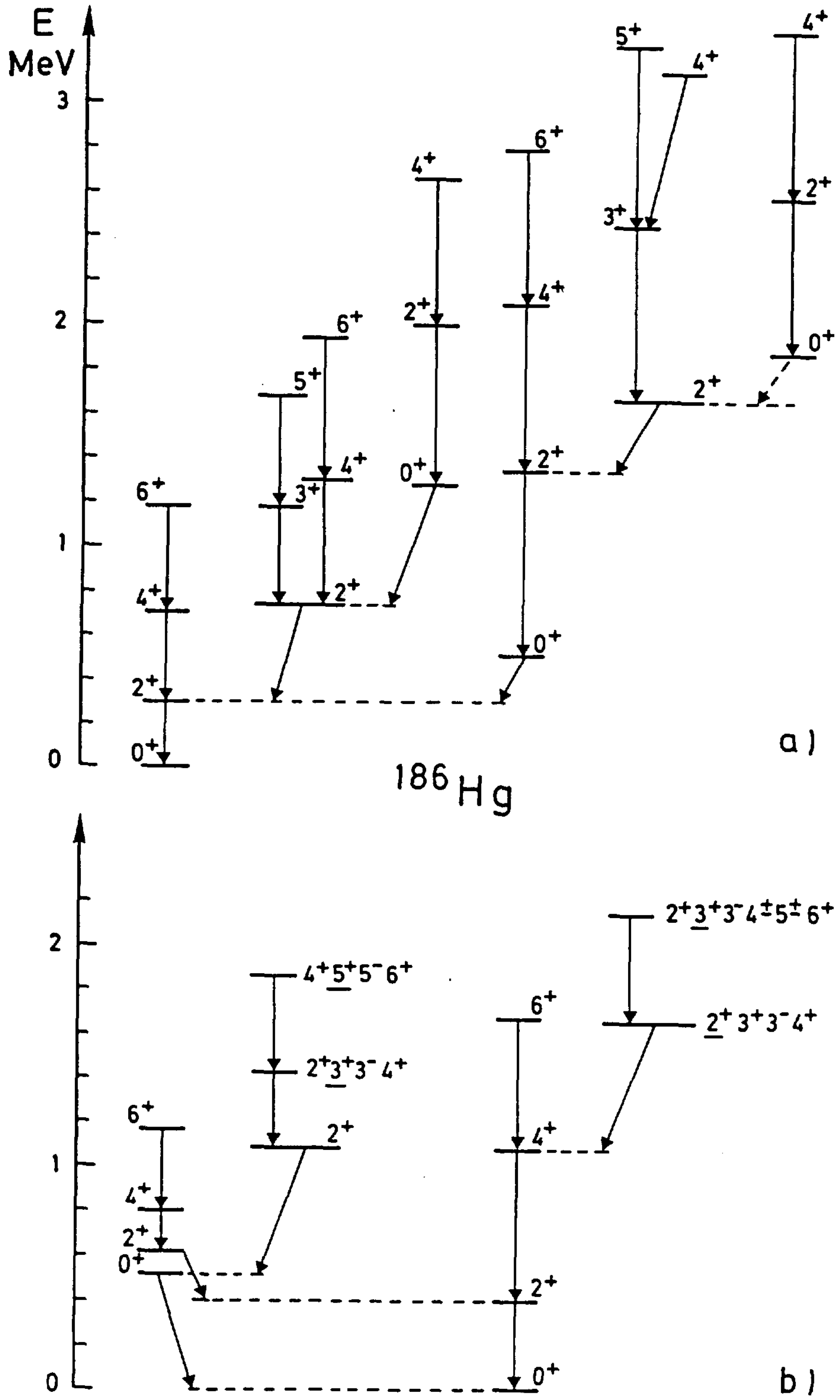

Fig. 1 Level schemes of ^{186}Hg with the largest reduced transition probabilities indicated by arrows. a) Theoretical predictions. b) Experimental results. All possible spin and parity values are reported and the chosen value is underlined.
The levels corresponding to the well-deformed prolate shape are drawn on the left and those corresponding to the quasi-spherical shape on the right. We can see that there is an energy inversion of the two structures between theory and experiment.

Abstract of ref. 3

Evidence for γ -vibrations and Shape Evolutions Through the Transitional ^{184,186,188,190}Hg Nuclei

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Abstract

Constrained Hartree-Fock-Bogoliubov calculations based on Gogny's force are performed to determine potential energy surfaces, collective masses and moments of inertia that are used to build a five dimensions collective Hamiltonian treating quadrupole motion in the ^{184,186,188,190}Hg isotopes. Many collective states are predicted at low excitation energy, some of them forming γ vibrational bands. To challenge our predictions and expand experimental information on γ bands which so far have escaped detection in all neutron deficient Hg isotopes but ^{188}Hg, high statistics measurements on the β^{+}/EC decay of ^{190}Tl^{g,m} and ^{186}Tl^{g,m} have been performed using ISOCELE facility. γ -bands are for the first time identified in ^{190}Hg and ^{186}Hg. These new results together with previous experimental information available on the ground state and K=0 excited bands in ^{184,186,188,190}Hg form a database which is analyzed and discussed in the present theoretical framework. It is argued that the first K=0 excited band in ^{190}Hg is a β vibrational band. For the lighter Hg isotopes, our calculations sustain the picture of shape coexistence taking place between $K = 0$ bands. Coexistence phenomena between γ bands are also predicted and observed for ^{186}Hg.