SEARCH FOR FIRST 0^+ EXCITED STATES IN ^{108}CD AND ^{106}CD

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Abstract

The ^{108}Cd and ^{106}Cd isotopes have been studied from the β^+/EC decay of ^{108}In and ^{106}In, with the on-line ISOCELE separator facilities. γ-rays, conversion electrons, γ-γ-t and e^--γ-t coincidence measurements have been performed. Level schemes of ^{108}Cd and ^{106}Cd have been deduced from our results. A 0^+ level has been unambiguously established at 1.913 MeV in ^{108}Cd and a new 0^+ level proposed at 2.035 MeV in ^{106}Cd. The energies and branching ratios are discussed in terms of vibrator + particles approach, interacting boson approximation and rotor + quasi-particles model.

1. Introduction

The cadmium nuclei (Z = 48) belong to the transitional region situated between the semi-magic tin nuclei and the more deformed zirconium ones. With only two protons from the closed shell (Z = 50) they are analogous to the mercury nuclei with respect to lead.

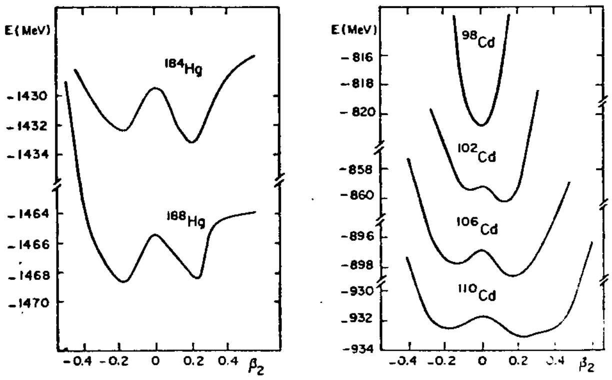

Fig. 1 - Deformation energy curves of even-even Hg and Cd obtained from HF calculations using the SIII effective interaction with the Δ constant pairing prescription.

Shape coexistences have been clearly established in the mercury nuclei [1,2]. Furthermore, deformation energy curves obtained for the Hg and Cd isotopes [3,4] (fig. 1) exhibit some similitudes. Except the semi-magic $^{98}_{48}$Cd$_{50}$ expected spherical, the Cd and Hg nuclei are found to be quite soft and a common feature of all these potential energy surfaces in the existence of two minima closed in energy, one oblate and the other prolate. The even-even Cd nuclei are however predicted prolate in fairly good agreement with the experimental Q_{2^+} values [5]. So we searched for a low-lying energy 0_{2^+} excited state corresponding to an oblate shape in both ^{108}Cd and ^{106}Cd nuclei.

2. Experimental Procedure

The ^{108}Cd and ^{106}Cd nuclei have been studied from the β^+/EC decay of ^{108}In and ^{106}In. The In isotopes have been produced by the Orsay synchrocyclotron through the reactions Sn(^{3}He$_{270\ \mathrm{MeV}}$,3pxn)In, Sn($\alpha_{200\ \mathrm{MeV}}$,3pxn)In and Sn($p_{200\ \mathrm{MeV}}$,2pxn)In reactions (fig. 2). The ^{3}He,α,p beams maximum intensities are 1 μA, 1 μA and 2 μA respectively, so we choose to use the ^{3}He beam for the ^{108}Cd study and the p beam for the ^{106}Cd one.

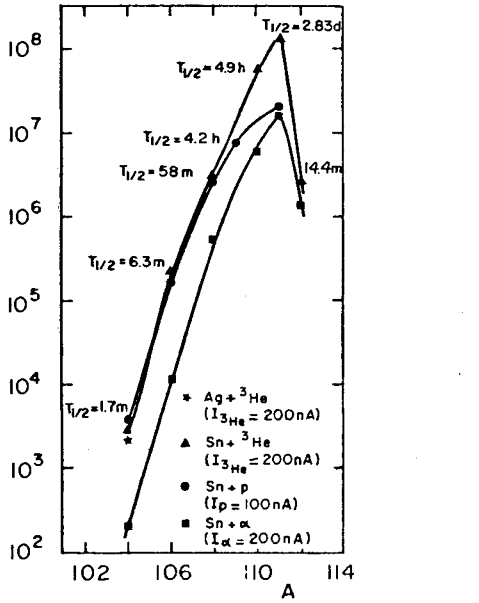

Fig. 2 - Yields (in atoms par second) of In nuclei from molten Ag and Sn targets.

The In isotopes, produced in the target, are extracted by evaporation, then mass separated with the on-line ISOCELE II separator [8]. The mass separated activities are transported on a tape from the collecting point to the counting one, using a mechanical tape transport system. Single γ and coincident three dimensional γ-γ-t spectra have been measured by means of two Ge (HP) detectors. The conversion electrons have been performed with a Si(Li) detector and e^--γ-t coincidence events have been also recorded.

3. Experimental Results

3.1 Level schemes

The ^{108}Cd and ^{106}Cd nuclei have been already studied from ^{108}In and ^{106}In decay [7-9]. The level schemes built from our results is in agreement with the previous ones. However many new levels have been observed, especially in the 3.3 MeV-5 MeV energy range. Figure 3 shows partial level schemes. In both nuclei, we can notice

- a collective (0_{1^+}, 2_{1^+}, 4_{1^+}, 6_{1^+}) built on the ground state
- a 2_{2^+} state lying closed to the 4_{1^+} one
- 4_{2^+} and 6_{3^+} states, the nature of which is probably the same in both nuclei (table 1)
- the existence of a 0_{2^+} state : in ^{108}Cd, the 0_{2^+} state at 1913,2 keV of energy decays to 2_{1^+} and 2_{2^+} states and to the ground state by a E0 transition. In order to establish unambiguously the E0 character of this transition, we have estimated the lower value of the conversion coefficient : $\alpha_K^{exp} > 10\ \alpha^{th}(M4)$. In ^{106}Cd, we propose an excited 0_{2^+} state at an energy of 2034.8 keV. This 0_{2^+} state decays to the 2_{1^+} state but not to the 2_{2^+} one (table 1).
- two 5^- states which are weakly fed
- a 6_{2^+} level strongly populated in the decay ^{108}In
- a 8_{1^+} level in ^{106}Cd this level has the most intensity feeding

B(E2) ratios	^{108}Cd	^{106}Cd
$\dfrac{4_{2^+} \rightarrow 4_{1^+}}{4_{2^+} \rightarrow 2_{2^+}}$	1.9	1.1
$\dfrac{4_{2^+} \rightarrow 2_{1^+}}{4_{2^+} \rightarrow 2_{2^+}}$	0.05	0.01
$\dfrac{6_{3^+} \rightarrow 4_{1^+}}{6_{3^+} \rightarrow 4_{2^+}}$	0.08	0.15
$\dfrac{0_{2^+} \rightarrow 2_{2^+}}{0_{2^+} \rightarrow 2_{1^+}}$	1070	< 500

Table 1 - Transition probabilities ratios of the 4_{2^+}; 6_{3^+}, 0_{2^+} states in ^{108}Cd and ^{106}Cd

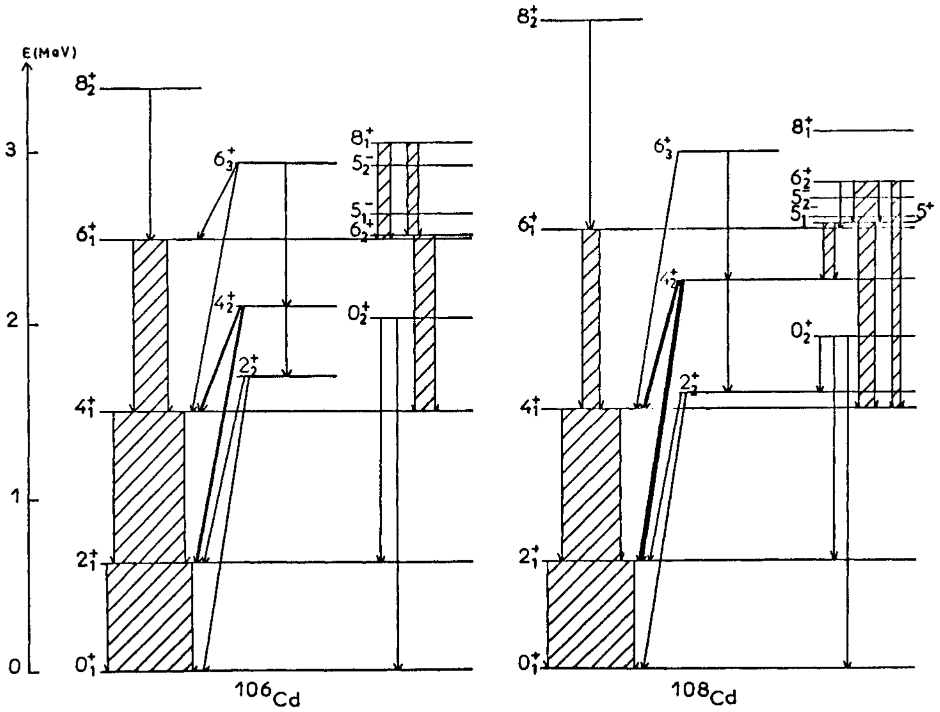

Fig. 3 - Partial level schemes of $^{106-108}$Cd deduced from our measurements

3.2 Isomeric states spins of ^{108}In and ^{106}In

Isomeric states spins of ^{108}In and ^{106}In have been already discussed by several authors [7-10]. The present work leads to propose 7^+ as spin and parity for the high spin isomeric state of ^{108}In and ^{106}In. More than 95% of the intensity has been placed in both decay schemes and the log ft values have been deduced. In ^{108}Cd, the 6^+ level at 2807.5 keV exhausts 40% of the total feeding. The log ft value is only consistent with $\Delta J = 0, 1$ and $\Delta\pi = +$. In contradiction with S. Flanagan et al.[7], the 5^- level at 2601.5 keV is not significantly fed in our experiment. Thus we prefer the 7^+ assignment for the isomeric state of ^{108}In.

In ^{106}Cd, three states are preferentially populated by the $^{+}$/EC decay of ^{106}In : the 8^+ state at 3044.4 keV (∿ 30 %) and the two 6^+ states at 2503.3 keV and 2491.8 keV (∿ 10 %). For these three levels, the log ft values are only consistent with ΔJ = 0,1 and $\Delta\pi = \pm$. We deduced that the isomeric state of ^{106}In has $7^{\pm}$ spin and parity. However the positive parity is assigned taking into account the only two possible configurations $\nu g^{7/2}$ $\pi g^{9/2}$ and $\nu d^{5/2}$ $\pi g^{9/2}$ for this state.

4. Discussion

In order to understand the nature of the 0^+ excited states observed in the ^{108}Cd and ^{106}Cd nuclei, let us compare their low-lying states to those observed in some neighbouring even-even isotopes (fig. 4). The first excited state 0_{2^+} energy shifts slowly from ^{116}Cd to ^{110}Cd but there is a sudden rise in energy from ^{110}Cd to ^{108}Cd. ^{110,112,114,116}Cd nuclei have long been regarded as vibrational nuclei with their typical triplet 0_{2^+} 2_{2^+} 4_{1^+} at around 1.3 MeV excitation energy. In ^{108}Cd and ^{106}Cd, the observed 0_{2^+} states are too high in energy to belong to such a triplet. Neither can they be interpreted as head state of a collective band corresponding to another shape than that of the ground state (as in Hg nuclei), since no state decays to them.

Within the framework of the particle vibrator coupling model, V. Lopac[11,12]) calculated the low-lying states of ^{108}Cd. The level energies and the transition probabilities of the 2_{1^+}, 4_{1^+} and 2_{2^+} levels have been rather well reproduced in this model. Theoretically the 0_{2^+} state decays mainly to the first 2^+ level and weakly to the second 2^+ one in contrast with experiment (fig. 5 and table 2).

The IBA2 model of Iachello and Arima[13]) has been applied to the Ru and Pd nuclei[14]). This model could describe the evolution of the low-lying levels of Cd nuclei. Figure 6 shows that the evolution in energy of the 2_{1^+}, 4_{1^+} and 6_{1^+} levels is consistent with an extrapolation of theoretical curves from Ru and Pd to Cd. Concerning the 0_{2^+} level, the IBA2 model provides a sudden rise in energy between N = 60 and N = 58 in Ru and Pd nuclei. Experimentally in Cd isotopes, this feature is observed between N = 62 and N = 60. Unfortunately the decay mode of this 0_{2^+} state has not been studied in the IBA2 model applied to Ru and Pd nuclei. However it would be surprising that this model could reproduce such a sudden change in the 0_{2^+} decay mode between ^{108}Cd and ^{106}Cd since the model parameters follow a smooth variation with the nucleon number.

In conclusion, we have observed 0^+ excited states in ^{108}Cd and ^{106}Cd which cannot be understood in terms of shape coexistence. These states seem to have rather a particle nature (neutron excitations). To interpret high spin states, observed in HI reactions, L.E. Samuelson et al.[15]) have suggested the axial rotor + two quasi-particles model. It would be fruitful to extend this model to low spin states. The decay mode of these "intruder" 0^+_2 states would make up a stringent test of its validity.

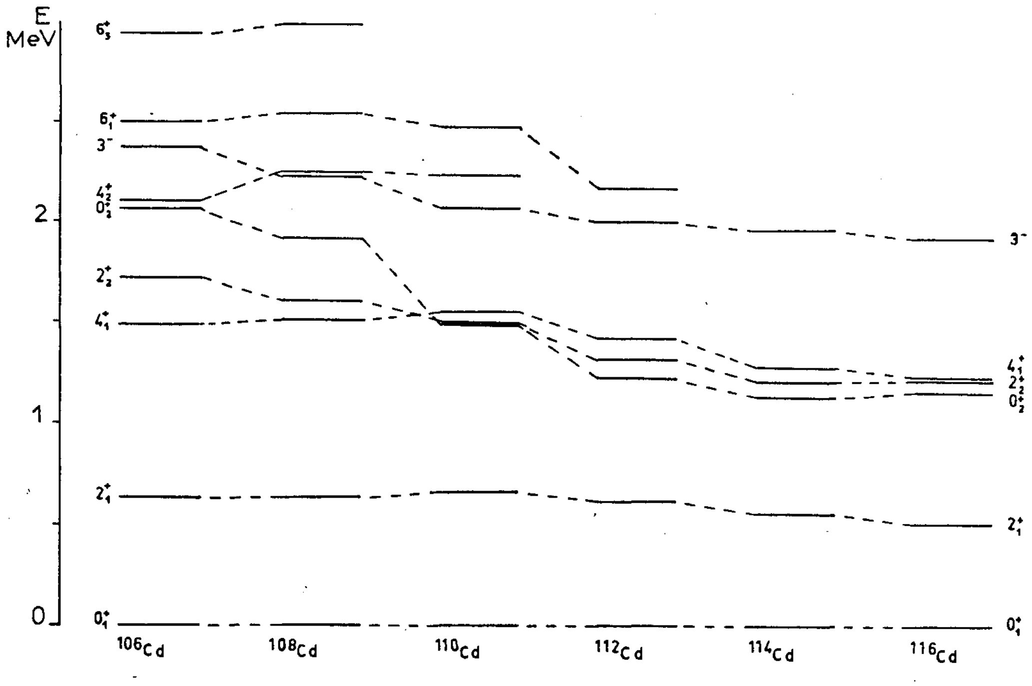

Fig. 4 - *Systematics of first excited levels in Cadmium isotopes.*

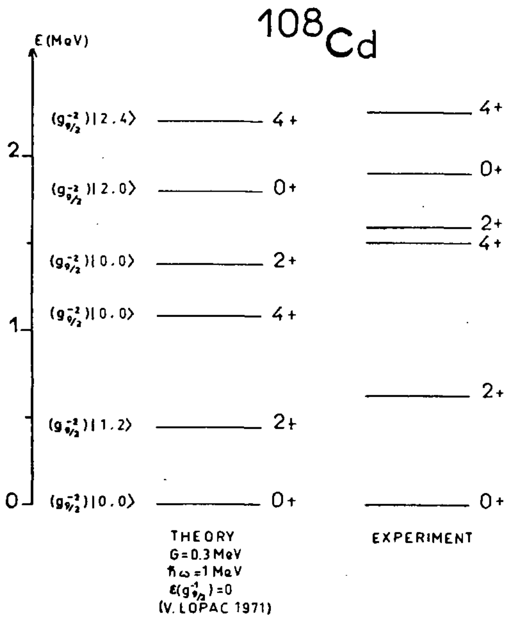

Fig. 5 - Comparison between experimental level scheme of ^{108}Cd and the theoretical one calculated in the vibrator + particles model 12).

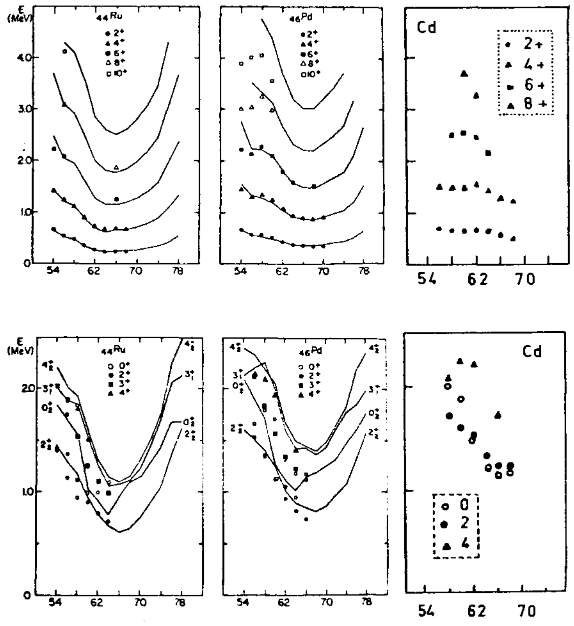

Fig. 6 - Comparison between experimental (points) and calculated energies for the lowest states in the Ru, Pd and Cd isotopes within the IBA2 model 14).

Transition	B(E2)$_{exp}$)	B(E2)$_{th}$	Ratio	Exp	th
$2_1^+ \to 0_1^+$	0.082	0.088	$\frac{0_2^+ \to 2_2^+}{0_2^+ \to 2_1^+}$	1070	0.05
$2_2^+ \to 0_1^+$	0.0059	0.003	$\frac{2_2^+ \to 2_1^+}{2_2^+ \to 0_1^+}$	11	23
$4_1^+ \to 2_1^+$	0.122	0.130			

Table 2 - Absolute and relative values of transition probabilities (in e^2b^2) in ^{108}Cd.

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