Intrinsic and Collective $^{166}$Er Levels Fed in the Decays of $^{166}$Ho$^m$ ($T_{1/2} = 1200\text{ y}$) and $^{166}$Ho$^g$ ($T_{1/2} = 26.8\text{ h}$).

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Summary. — The radioactive decays of $^{166}$Ho isomers ($I^e = 7^-$ and $0^-$) have been reinvestigated using high-resolution γ-ray detectors in single and coincidence measurements. Nine γ-lines are new, among the fifty-three γ-lines accurately measured belonging to $^{166}$Ho$^m$ decay ($I^e = 7^-$); sixteen γ-lines were measured in $^{166}$Ho$^g$ decay ($I^e = 0^-$) out of which 3 are new; moreover, γ-γ coincidence experiments using two germanium detectors were performed. A $^{166}$Er level scheme was built which interprets all γ-lines measured: two new levels are proposed to be fed in the $^{166}$Ho$^m$ decay, namely the $K_1^e = 22^+$ at 785.5 keV and a $I^e = 4^-$ state at 1572.1 keV; in $^{166}$Ho$^g$ decay, the $K_1^e = 0_2^+$ state in $^{166}$Er is confirmed, and a new level is found at 1812.8 keV ($I^e = 1^+$). Spin, parity and Nilsson orbitals assignments of the intrinsic $^{166}$Er states are discussed.

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1. – Introduction.

The levels of the strongly deformed $^{166}$Er nucleus have been studied in the past years using different reactions: single-nucleon transfer reactions, such as $^{166}$Er(d, t) [1], $^{165}$Ho($^3$He, d), $^{165}$Ho(x, t) [2, 3],

were preferred to evidence the two quasi-particle structure, while inelastic scattering $^{166}$Er(d, d') reaction [4] was used to observe collective excitations.

More recently, the $^{166}$Er rotational side bands were studied by Fields et al. [5] through the $^{166}$Dy(x, 2nγ) reaction; the $^{166}$Er ground-state band was excited up to spin $I = 16$, the γ-vibrational band up to $I = 14$ and some negative-parity bands up to spin $I^e = 9, 10^{-}$. The most extensive study concerning the electromagnetic decay properties of $^{166}$Er low-energy states is that of Reich and Cline[6] which have investigated both $^{166}$Ho$^m$ ($T_{1/2} = 1200\text{ y}$) and $^{166}$Ho$^g$ ($T_{1/2} = 26.8\text{ h}$) decays.

A more recent investigation of $^{166}$Ho$^g$ decay performed by Allab et al. [7], on a
low-activity source, synthetized using a $^{252}$Cf source facilities, revealed the existence of new $\gamma$-lines. Besides, preliminary results of a $^{166}$Ho$^m$ $\gamma$-ray spectrum measurements have been published elsewhere [8].

2. - Experimental details.

2'1. Radiochemical separations. – The long-lived $^{166}$Ho$^m$ nuclide was provided by the L.M.R.I. (Laboratoire de Métrologie des Rayonnements Ionisants) as a standard HoCl$_3$ source with a nominal activity of 48.5 kBq. Preliminary measurements of $\gamma$-spectra showed a weak ($\approx 0.1\%$) contamination by long-lived rare-earth nuclides, such as $^{152}$Eu and $^{154}$Eu. Hence, a radiochemical separation was required to warrant the attribution of the new $\gamma$-lines observed.

The $^{166}$Ho$^m$ source was put on the top of a 12.5 cm length and 0.05 cm$^2$ area column, filled with a DOWEX 50W-X8 cation exchanger. The elution was performed, at room temperature, using a 0.51 M ammonium z-hydroxy-isobutyrate solution (HIB) adjusted to $\rho$H = 3.3 with a NH$_3$, H$_2$O solution; the holmium fraction was first collected in less than 1.5 cm$^3$ volume, as was stated by Smith and Hoffman [9], and the europium fraction passed after 14 CV (column volume). The holmium fraction was finally evaporated on a plastic disk for $\gamma$-counting.

As concerns the $^{166}$Ho$^6$ decay isomer, the source was obtained by irradiation of a 2 mg weight Ho$_2$O$_3$ target with a neutron flux of $2.5 \times 10^{13}$ n cm$^{-2}$ s$^{-1}$ and one-day irradiation time. The separation procedure was started after a 2 days cooling time, when the activity was approximately lowered to 1.5 GBq. The radiochemical separation was essentially the same that we used for $^{166}$Ho$^m$, except that the $\rho$H of the HIB solution was adjusted to 3.1, to obtain a better separation from rare-earth impurities such as $^{175}$Yb, which was observed in the first fractions. The holmium fraction was evaporated to dryness on an aluminium plate.

2'2. Spectrometry. – The detectors used in $\gamma$-measurements were mainly a coaxial HPGe detector (EG&G Ortec), having a 17% relative efficiency and an energy resolution (FWHM) of 1.9 keV on the 1.33 MeV photopeak of $^{60}$Co and a LEPS (Low Energy Photon Spectrometer) of 2 cm$^3$ active volume having a FWHM of 500 eV at the 122 keV $\gamma$-line of $^{57}$Co. An additional Ge(Li) detector of 8% relative efficiency was used for $\gamma$-$\gamma$ coincidence experiments.

The pulses of the detectors were analysed with a 8192 channels ADCAM multi-channel buffer (EG&G Ortec), coupled with a PDP11/23 disk-based microcomputer. File spectra were transferred to a VAX 8530 computer and analysed with the well-known GAMANAL computer code [10].

3. – Measurements.

3'1. Single $\gamma$-spectra. – Owing to the weak specific activity of the $^{166}$Ho$^m$ source, several $\gamma$-spectra were recorded in different geometries, with source to detector distances being limited to (0 ÷ 30) cm to control summing effects which are enhanced in the occurrence of strong $\gamma$-lines in cascade (see, for example, ref. [11]).

Figure 1 exhibits a typical $^{166}$Ho$^m$ $\gamma$-spectrum measured with the 17% coaxial HPGe detector; in order to resolve close energy doublets, $\gamma$-spectra were also measured with the LEPS detector, with an energy dispersion of 0.1 keV/channel (fig. 2).