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DECAY SCHEMES OF In^{116} (13 sec) : A 0^+ LEVEL IN Sn^{116}

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Rapport C.E.N. - BLG 150

DECAY SCHEMES OF In^{116} (13 sec) : A 0^+ LEVEL IN Sn^{116} (*)

Summary. - The gamma-ray spectrum associated with the decay of In^{116} (13 sec) has been studied using the fast pneumatic rabbit of the BR1 reactor at Mol. Four lines have been observed at 0.45, 1.28, 2 and 2.02 MeV. A decay scheme of In^{116} (13 sec) to levels of Sn^{116} is proposed from these results. It involves a level at 1.72 MeV in Sn^{116} whose 0^+ character is confirmed by the present experiment.

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DECAY SCHEMES OF In^{116} (13 sec) : A 0^+ LEVEL IN Sn^{116} (*)

Résumé. - Le spectre gamma associé à la désintégration de In^{116} (13 s) a été étudié au moyen du convoyeur pneumatique rapide installé au réacteur BR1 de Mol. Quatre raies ont été relevées à 0,45, 1,28, 2 et 2,02 MeV. Un schéma de désintégration de In^{116} (13 s) vers les niveaux de Sn^{116} est proposé sur la base de ces résultats. Il comporte un niveau à 1,72 MeV dans Sn^{116} dont le caractère 0^+ est confirmé par le présent travail.

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DECAY SCHEMES OF In^{116} (13 sec) : A 0^+ LEVEL IN Sn^{116} (*)

Samenvatting. - Het gammaspektrum verbonden met het verval van In^{116} (13 s) werd onderzocht met behulp van het snelle pneumatische "rabbit" van de BR1-reaktor te Mol. Er werden vier overgangen waargenomen respektievelijk bij 0,45, bij 1,28, bij 2 en bij 2,02 MeV. Een vervalschema van In^{116} (13 s) naar niveaus van Sn^{116} werd voorgesteld aan de hand van deze resultaten. Het bevat een niveau in Sn^{116} bij 1,72 MeV, waarvan het 0^+-karakter door dit experiment werd bevestigd.

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DECAY SCHEMES OF In^{116} (13 sec): A 0^+ LEVEL IN Sn^{116}

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The energy levels of the Sn isotopes have recently been calculated by several authors in the framework of the pairing theory [1-3] and their experimental study is of considerable interest. In particular the levels of Sn^{116} can be excited by the decay of In^{116} (13 sec), In^{116} (54 min), Sb^{116} (15.5 min) and Sb^{116} (60 min) (ref. [4]). The ground state In^{116g} of In^{116} decays by a 3.29 MeV β^- transition to the ground state of Sn^{116} with a 13 sec half-life [4,5]; according to Boley [5], no γ-rays are present in its decay. We have re-investigated the γ-ray spectrum associated with the decay of In^{116g} in order to determine whether excited states of Sn^{116} can be reached from In^{116g} This nucleus was prepared by thermal neutron capture in In^{115} using the fast pneumatic rabbit installed at the BR1 reactor at Mol and described elsewhere [6]. The γ-ray spectrum has been registered with a 2" × 2" NaI(Tl) crystal and a multichannel analyser; gamma-gamma coincidences were studied with a fast-slow coincidence circuit (resolving time: 2τ = 2×10^{-8} sec).

Fig. 1 shows the γ-ray spectra of a natural indium sample registered respectively 5 sec (curve a) and 1.5 min after the irradiation (curve b); the latter displays the contribution of In^{116m1}, the 54 min isomer of In^{116}, whose decay is well known [4,7]. The difference between the two (curve c) only in-

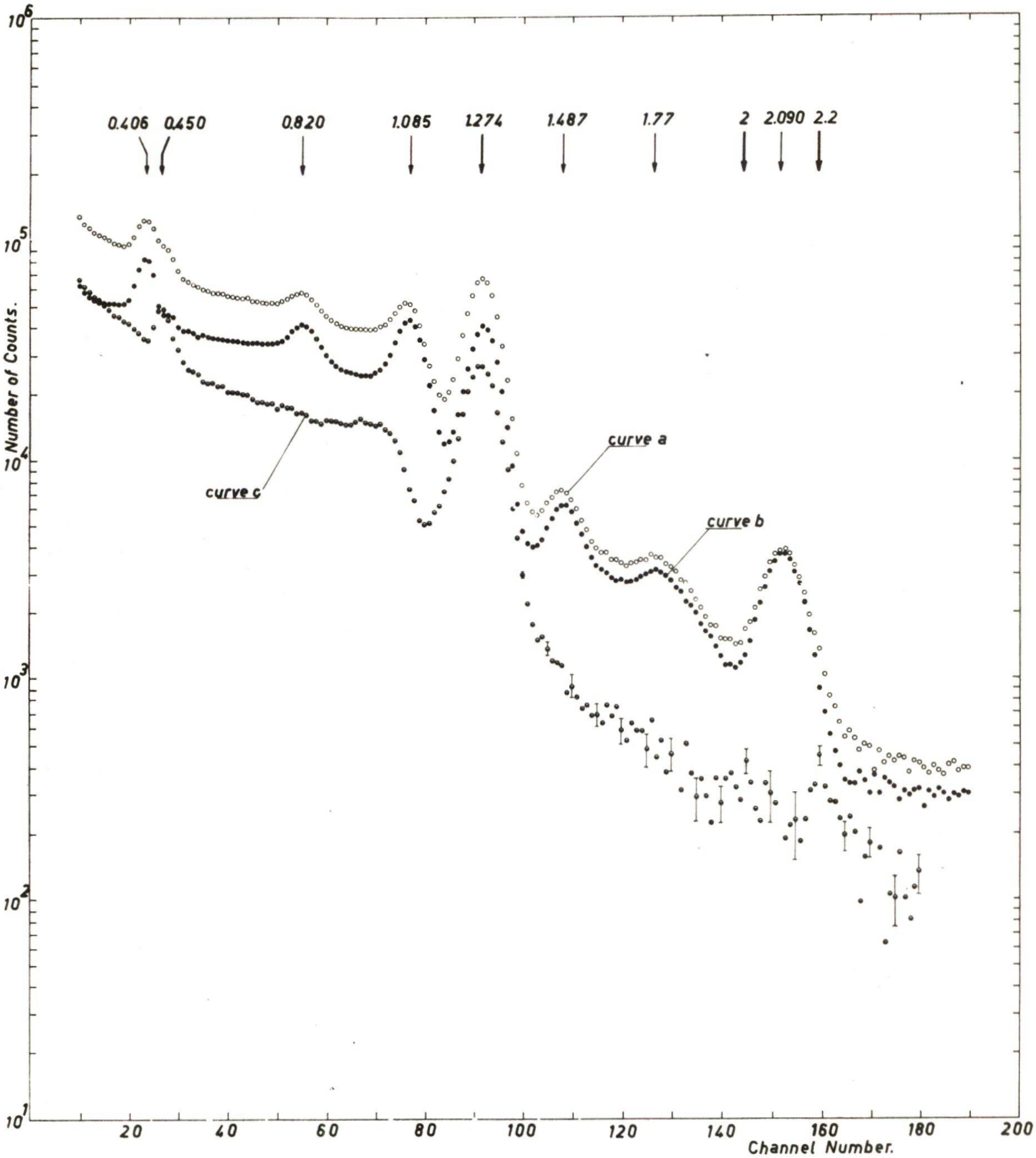

Fig. 1. Gamma-ray spectra of a natural indium sample irradiated for 5 sec in the reactor, registered respectively 5 sec (curve a) and 1.5 min after the irradiation (curve b). Curve c is the difference between curves a and b. The γ-ray energies are given in MeV. The γ-ray lines indicated by thin arrows are found in the γ-ray spectrum of In^{116m1} (curve b) and their energies are taken from ref. [4]). The lines indicated by thick arrows are found in the spectrum of In^{116g} (curve c) and their energies are determined in the present experiment. The 1.274 MeV line is common to both spectra.

cludes the short half-life components of the spectrum, i.e., the contribution of In^{116g}: the 0.150 MeV isomeric transition from In^{116m2}, the 2.5 sec isomer of In^{116} (ref. [4,8])) has been biased off for experimental reasons. The spectrum of curve c contains 2 prominent lines at 0.450 $\pm$ 0.015 and 1.270 $\pm$ 0.015 MeV, 2 weak lines at about 2 and 2.2 MeV and a γ-ray continuum between the 0.45

and 1.27 MeV lines and above the latter. This continuum is attributed to the bremsstrahlung from the intense 3.29 MeV β^- transition which represents most of the decay of In^{116g}; its shape has been approximately determined with a Sr^{90}-Y^{90} source. A detailed analysis of the spectrum of curve c in its components reveals a line at about 0.95 MeV whose energy and intensity can only be estimated with wide limits of error in view of the uncertainty in the bremsstrahlung contribution. The relative intensities, in the decay of In^{116g}, of the 0.45, 0.95, 1.27, 2 and 2.2 MeV are respectively 0.12 ± 0.02, 0.10 ± 0.05, 1.25 ± 0.02, 0.015 ± 0.008 and 0.025 ± 0.013%.

The half-life associated with the intense lines at 0.45 and 1.27 MeV has been measured to be 13 sec, apart from 54 min components; we have checked, by the use of enriched isotopes, that they are associated with the decay of In^{116g}: this is in direct contradiction with the results of Boley [5]. Coincidence experiments have shown that the 0.45 and 1.27 MeV lines are in cascade in the decay of In^{116g}; the half-life of In^{116g} is too short to allow angular correlations to be performed on this cascade. The 1.27 MeV γ-ray is also present in the decay of In^{116m1} (curve b) where it represents the ground state transition from the 2^+ first excited state of Sn^{116} (ref. [4]); this is probably its origin in the decay of In^{116g} too. As the 0.45 MeV line is in coincidence with and of lower intensity than the 1.27 MeV line, one can conclude that In^{116g} decays not only to the 0^+ ground state of Sn^{116} but also to the 2^+ first excited state at 1.27 MeV and to a level at 1.72 MeV in Sn^{116}.

Sb^{116} (15.5 min) decays to the first and third 2^+ states at 1.27 and 2.2 MeV in Sn^{116} but not to the second at 2.09 MeV [9]. The 2.2 MeV level in Sn^{116} decays to the first excited state by a 0.9 MeV transition and to the ground state, the ratio cascade/cross-over being 3.9 (ref. [9]). As γ-ray lines are present at about 0.95 and 2.2 MeV in the decay of In^{116g} with an intensity ratio of the order of 4, one can conclude that the 2^+ level at 2.2 MeV in Sn^{116} is also reached in the decay of In^{116g}. Upper limits have been assigned to the intensity, in the spectrum of curve c, of a possible 1.72 MeV cross-over transition for the 0.42 - 1.27 MeV cascade and of a 2.09 MeV γ-ray present in the decay of In^{116m1} where it represents the ground state transition from the second 2^+ state in Sn^{116} (ref. [4]); these limits are respectively 0.008 and 0.003%. One can conclude that the second 2^+ state in Sn^{116} is not excited in the decay of In^{116g}, whereas the first and third are reached. This situation is analogous to that existing in the decay of Sb^{116} (15.5 min) and points towards a difference in "nature" for the second 2^+ state in Sn^{116} as compared with the first and third.

From the intensities of the various lines in the γ-ray spectrum associated with the decay of In^{116g}

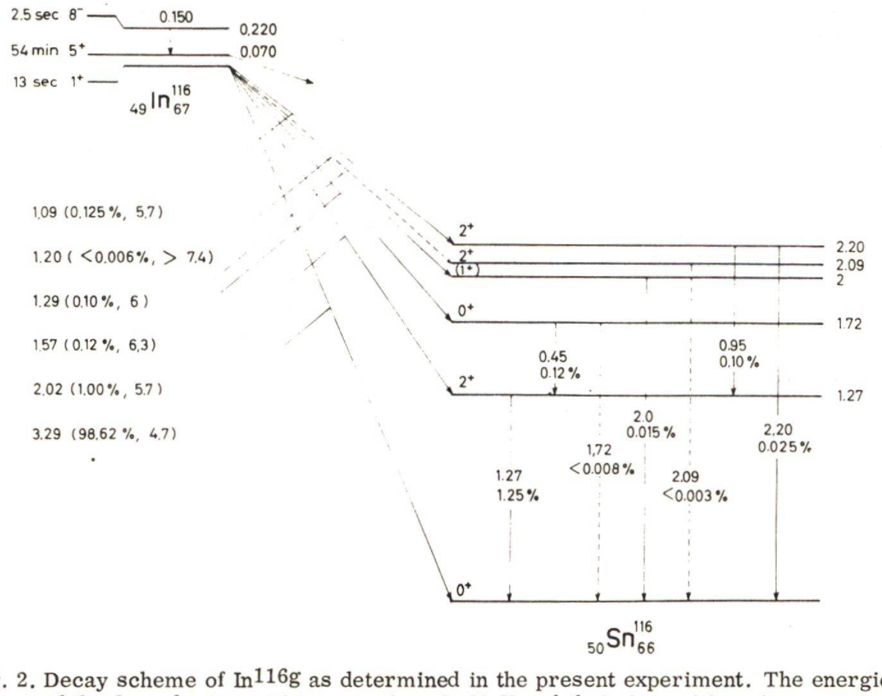

Fig. 2. Decay scheme of In^{116g} as determined in the present experiment. The energies of the β^- and γ transitions are given in MeV and their intensities, in percent of the In^{116g} decay. The data given for the β^- transitions are successively their energy, intensity and log *ft* value.

or from their upper limits, one can calculate the log *ft* values for the various β^- transitions or their lower limits; the results are indicated in the decay scheme of In^{116g} given in fig. 2. The existence of allowed β^- transitions from In^{116g} to the 0^+ ground state and 2^+ first excited state of Sn^{116} shows that the spin and parity of In^{116g} are 1^+.

The 1.72 MeV level in Sn^{116} probably has a 0^+ character: the β^- transition exciting this level from In^{116g} is allowed and no transition from this level to the ground state of Sn^{116} has been detected. Using the (d,p) and (d,t) reactions on $Sn^{115,117,119}$, Cohen and Price [10,11] have excited levels at 1.56, 1.75, 1.75, 1.89 MeV respectively in $Sn^{114,116,118}$ and Sn^{120}; the angular distribution of the corresponding proton groups in the (d,p) reaction shows that the spin and parity of these levels in $Sn^{116,118}$ and Sn^{120} are 0^+ or 1^+. The 0^+ level observed at 1.72 MeV in Sn^{116} during the present experiment can probably be identified with the 1.75 MeV level excited by Cohen and Price in this nucleus. It is likely that the similar levels in $Sn^{114,118,120}$ also have a 0^+ character.

Price [11] has excited by the $Sn^{115}(d,p)Sn^{116*}$ reaction a 0^+ or 1^+ level at 2.02 MeV in Sn^{116}. The weak 2 MeV line we have observed in the γ-ray spectrum associated with the decay of In^{116g} could be assigned to the ground state transition from this level which should then have a 1^+ character.

The 0^+ levels in $Sn^{114,116,118,120}$ may be identified with the $(S_{\frac{1}{2}})^2$ two identical quasi-particle states predicted in this energy region by Kisslinger and Sorensen [1]. They are also predicted by the calculations of Arvieu et al. [3] on the energy levels of the Sn isotopes, although their experimental energies are higher than the theoretical ones. These 0^+ levels may also be members of the 0, 2, 4 two-phonon triplet in a vibrational model, although their excitation energy is appreciably below twice the energy of the first 2^+ states. If the ratio of the energies of the first 0^+ and 2^+ levels in even nuclei is plotted against mass number (fig. 3), most experimental values cluster around 2, the prediction of a simple vibrational model. This ratio is appreciably higher than 2 for rotational nuclei and smaller than 2 in the neighbourhood of closed shells. The situation in the even Sn isotopes fits well in this

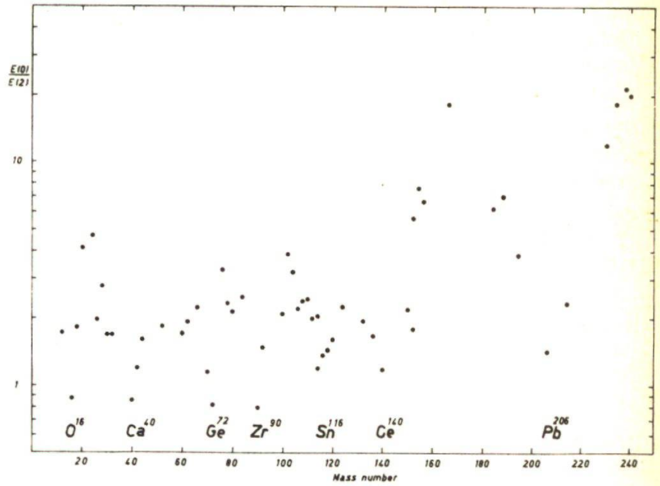

Fig. 3. Ratio $E(0)/E(2)$ of the energies of the first 0^+ and 2^+ levels in even nuclei as a function of mass number. The dashed line represents the theoretical value of this ratio (2) in a simple vibrational model.

system in view of the magic character of their proton number.

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