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THE ELECTRON CAPTURE DECAY OF ^{106m}Ag

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Abstract: The electron capture decay of 8.4d ^{106m}Ag has been investigated by means of a 4π internal source scintillation spectrometer and a Ge(Li) detector. The L/K capture ratios to the 2952 and 2757 keV excited states of ^{106}Pd have been measured: $(L/K)_{2952} = 0.203 \pm 0.003$ and $(L/K)_{2757} = 0.1457 \pm 0.0010$. The value of $Q = 3053 \pm 3$ keV has been deduced from these L/K ratios.

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RADIOACTIVITY ^{106m}Ag [from ^{106}Pd(d, 2n)]; measured $I_X + I_{\text{Auger}}$, γX-coin; deduced L/K, Q. Enriched targets; Ge(Li), NaI detectors. Internal source method.

1. Introduction

In a comparison of experimental and theoretical exchange and overlap corrections for L/K capture ratios Goverse [1]) has observed that the experimental corrections seem to oscillate about the theoretical curve. The suggestion of Goverse is that correlation effects between orbital electrons are a possible explanation of these discrepancies. The most recent compilation of electron capture data [2]), published after the termination of our experiments on ^{106m}Ag, however, shows no evidence for the suggestion that correlation effects take place. The decay of ^{106m}Ag has been studied to investigate Goverse's suggestion.

A partial decay scheme based on the recent compilation of Nuclear Data Sheets [3]) is given in fig. 1. The electron capture ratios of ^{106m}Ag have not been measured up to now.

An accurate Q-value is necessary for the determination of exchange and overlap corrections from electron capture ratios. According to the compilation of Nuclear Data Sheets the Q_{EC} value, i.e. the Q-value of the ground-ground transition, based on a measurement of the β^+ end-point energy [4]), is well known. However, the position of the $6^{(+)}$ isomeric level of ^{106}Ag is uncertain. Anderson *et al.* [5]) recently have located the isomeric level at 88 keV as a result of their work on the reactions ^{103}Rh(α, nγ)^{106}Ag, ^{107}Ag(p, d)^{106}Ag, ^{105}Pd(^{3}He, d)^{106}Ag and ^{104}Pd(^{3}He, p)^{106}Ag, but their placement of the level is tentative. Since it is possible to determine the Q-value from the L/K ratios for capture to two different levels, provided they have a different Q-dependence, the L/K capture ratios to the 2952 keV level and to the 2757 keV level have been measured.

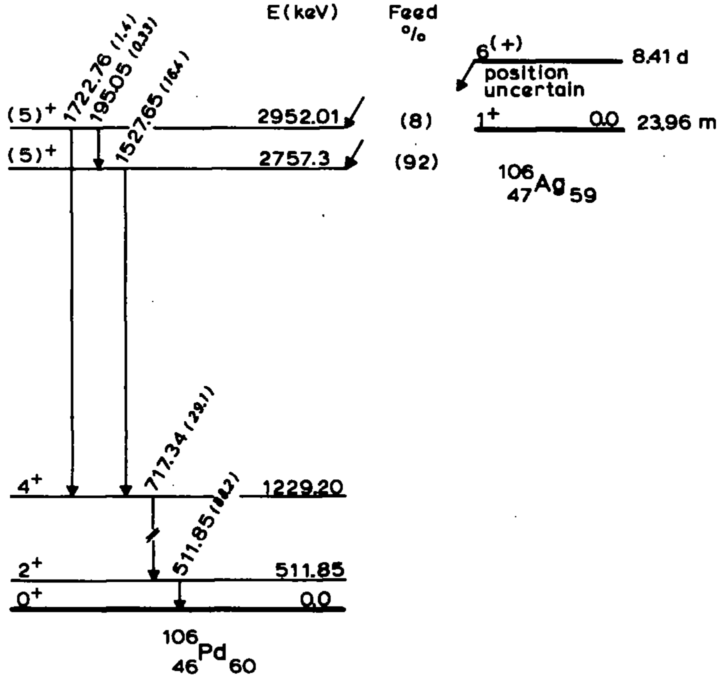

Fig. 1. Decay scheme of ^{106m}Ag.

According to the decay scheme of fig. 1, the decay is probably allowed or first-forbidden non-unique as the spin and parity of the isomeric state is $6^{(+)}$ and of the fed levels in ^{106}Pd $(5)^+$. Recently, however, the spin of the 2757 keV level has been determined by means of angular correlation experiments to be 5 [ref. [6])]. The Q-dependence of the L/K capture ratio is the same for allowed and first-forbidden non-unique decays. With the reservation that the decay to the 2952 keV level is either allowed or first-forbidden non-unique it was possible to determine the Q-value and the exchange and overlap correction factor $X^{L/K}$ from the two measured L/K ratios.

The 8.41 d ^{106m}Ag activity was produced by irradiation of more than 90% enriched ^{106}Pd with 18 MeV deuterons in the cyclotron of the "Instituut voor Kernfysisch Onderzoek" in Amsterdam.

2. Measurements

The X-rays and Auger electrons have been measured by means of a 4π internal source NaI(Tl) spectrometer [7]). The γ-rays were detected in a 75 cm^3 Ge(Li) detector. Comparing the experimental set-up with the one used in the former experiment [†] there is only one difference: after the main amplifier and the delay in the

[†] See the former article concerning the electron capture decay of ^{131}Ba.

X-ray branch a combination of a delay, a discriminator and a linear gate-stretcher was included. When a signal caused a limit pulse in the main amplifier, the following circuit discriminated against these pulses. This is particularly of importance since each capture event was accompanied with an energy release of 717 and of 512 keV. In the majority of these cases the energy releases were totally or partially detected in the crystal combination, giving a limit pulse. So it was very useful to discriminate against limit pulses to avoid a busy state of the ADC of at least 15 μsec per limit pulse. Also in this experiment a window has been set in the γ-ray spectrum by means of a single channel analyzer to select the γ-peak and a small part of the background at the right side of the γ-peak. In this way the γ-radiation could be recorded by a separate ADC to monitor its place and at the same time the background could be measured during the experiments.

Coincidence measurements have been performed with the 1723 keV γ-radiation de-exciting the 2952 keV level and with the 1528 keV γ-radiation de-exciting the 2757 keV level. The background under the L-K spectrum has been measured separately with the window selecting a part of the background at the high energy side of the 1723 keV γ-peak and at the low energy side of the 1528 keV γ-peak. In the latter case, the measurement of the background over a reasonable number of channels at the right side of the γ-peak was almost impossible because of the nearest 1572 keV γ-peak. The difference in background level at the right and left sides of the 1528 keV γ-peak was corrected for. Random coincidences have been measured with a non-radioactive crystal between the enveloping crystals and with equal window settings as for normal coincidence measurements.

3. Results

The typical energy spectra of the 4π NaI(Tl) spectrometer are given in figs. 2a, b. The background has not been subtracted. In an internal source spectrometer, the orbital electron binding energies are registered instead of the X-ray energies, assuming that the binding energy released in a capture event is detected at the proper energy. In the case of the K-peak this has been verified by means of an external calibration source ^{109}Cd, with an accuracy of 1.2 %.

3.1. BACKGROUND SUBTRACTION

From the measured energy spectra the following background subtractions must be made.

(i) Subtraction from the L-peak of background due to coincident summation of L X-rays with a partially detected energy release of 717 or 512 keV.

(ii) Subtraction of the same background from the K-peak.

(iii) Subtraction from the K-peak of background due to coincident summation of K X-rays with a partially detected energy release of 717 or 512 keV.

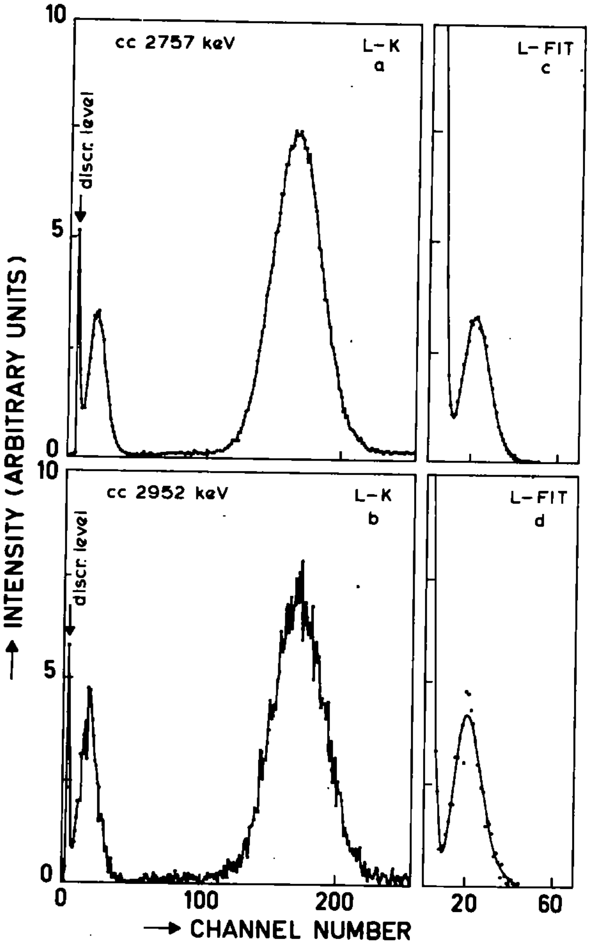

Fig. 2. Typical energy spectra and L-fittings. (a), (b) The energy spectra coincident with the 2757, 2952 keV γ-radiation, respectively. (c), (d) The corresponding L-peak fitting.

(vi) Subtraction of the contribution to the spectrum, coincident with background in the γ-peak selecting window, from the L- and K-peak. This background has been determined from the background measured next to the γ-peak during the measurements and from the count rate in the separately measured corresponding background coincident spectra. The contribution of random coincidences herein to the X-ray peaks was totally negligible.

The L-peaks in the L-K spectra were not completely resolved from the noise as we did not discriminate against photomultiplier and electronic noise by means of the dynode signals. The noise and the L-peak have been analysed by a computer fitting routine. This program fitted the noise with an exponential function and the L-peak with the Prescott-function in normalized form mentioned in the preceding paper. See figs. 2c, d.

3.2. L/K CAPTURE RATIO TO THE 2952 keV LEVEL

The L-K measurements coincident with the 1723 keV γ-radiation result in a L/K capture ratio of 0.203 ± 0.003. The correction for background coincident contribution in the measured ratios never exceeds 2.9 %.

3.3. L/K CAPTURE RATIO TO THE 2757 keV LEVEL

The measurements coincident with the 1528 keV γ-radiation result in a L/K capture ratio of 0.1457 ± 0.0010. The correction for background coincident contribution in the measured ratios never exceeds 1.67 %. The 2757 keV level is also fed by de-excitation of the 2952 keV level. This interference only occurs when the 195 keV γ-radiation escapes from the crystal assembly. When the 195 keV γ-ray is detected totally or partially or when conversion of the 195 keV de-excitation energy takes place, the interference is summed out of the L-K spectrum. However, this interference is calculated to be smaller than 0.03 % and is hence negligible.

3.4. DETERMINATION OF ERRORS

The errors made by the subtraction from the L- and K-peaks of the background due to coincident summation have been added quadratically to the statistical errors in the contents of the L- and K-peaks. The same has been done with the errors made by the determination of the contents of the K-peak. From the individual measurements, a weighted mean L/K ratio has been determined and the error herein is the weighted mean of the individual errors. The statistical uncertaincy in the correction for background coincident contribution has been added quadratically to this error. So the error in the final result is to be considered as a statistical one with a 1σ confidence level.

3.5. DETERMINATION OF Q AND $X^{L/K}$

The Q-value of the isomeric level can be calculated from the experimental L/K capture ratios to the 2952 keV level and the 2757 keV level, by equating the experimental reduced L/K capture ratios

$$\left.\frac{(\mathrm{L/K})}{(q_{\mathrm{L_I}}/q_{\mathrm{K}})^2}\right|_{2757} = \left.\frac{(\mathrm{L/K})}{(q_{\mathrm{L_I}}/q_{\mathrm{K}})^2}\right|_{2952}$$

Here, q_{K} and $q_{\mathrm{L_I}}$ are the neutrino energies in K and $\mathrm{L_I}$ capture respectively. With the help of this Q-value and the experimental L/K capture ratios the $X^{L/K}$ value can be calculated. In fig. 3 $X^{L/K}$ is plotted as a function of Q for the 2952 keV as well for the 2757 keV level. The intersection of both curves gives as result $Q = 3053 \pm 3$ keV and $X^{L/K} = 1.071 \pm 0.025$. The error in the Q-value is very small because of the very

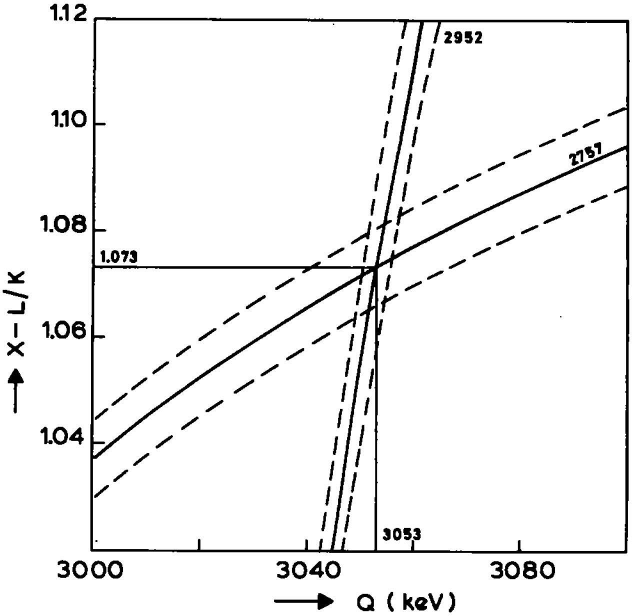

Fig. 3. The $X^{L/K}$ values as a function of Q.

sensitive Q-dependence of the L/K capture ratio to the 2952 keV level. In addition, the experimental reduced L/K capture ratio $(L/K)/(q_{L_I}/q_K)^2$ has been calculated to compare with the theoretical reduced L/K capture ratio $(g_{L_I}/g_K)^2[1+(f_{L_{II}}/g_{L_I})^2]$, resulting in $(L/K)/(q_{L_I}/q_K)^2 = 0.126 \pm 0.003$. Here, g_K, g_{L_I} and $f_{L_{II}}$ are the K, L_I and L_{II} electron wave functions respectively. In all these calculations we used the electron wave functions of Mann and Waber [8]) and the binding energies of Bearden and Burr [9]).

4. Discussion

4.1. THE Q-VALUE

The Q_{EC} values given by Nuclear Data Sheets of 2974 ± 10 keV and by Wapstra and Gove [10]) of 2974 ± 11 keV are based on a β^+ end-point energy measurement [4]). Together with our Q-value of 3053 ± 3 keV we can decide on an energy of the isomeric level in ^{106}Ag of 79 ± 11 keV. This supports the tentative location of the isomeric level at 88 keV by Anderson *et al.* [5]).

4.2. REDUCED L/K CAPTURE RATIOS

The theoretical value for this ratio calculated by Bambynek *et al.* [2]) according to the Bahcall approach is 0.124 and according to the Vatai approach is 0.123. With

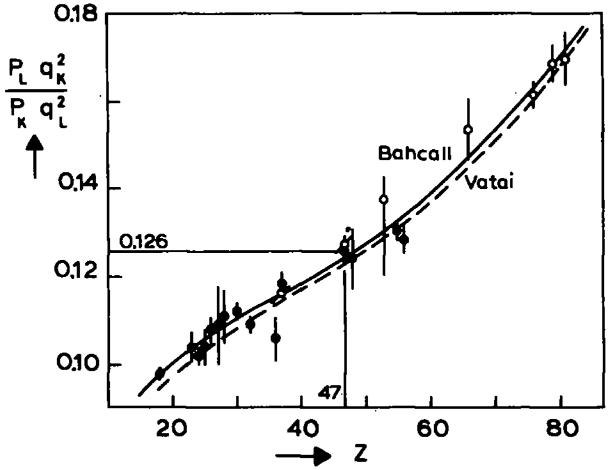

Fig. 4. Comparison of experimentally determined L/K capture ratios for allowed transitions (solid circles) and first-forbidden non-unique transitions (open circles) with theoretical predictions.

these two values our value of 0.126 ± 0.003 is in good agreement. On account of our result of 0.126 ± 0.003 for the reduced L/K capture ratio of ^{106m}Ag, however, it is impossible to make a distinction between the two given theoretical values; see also fig. 4 taken from ref. [2]). In this figure the reduced L/K capture ratio for ^{105}Ag of 0.126, calculated from the L/K ratios measured by Schulz [11]), has been changed to 0.127. From the L/K capture ratio of 0.152 ± 0.002 and the corresponding $(q_{L_I}/q_K)^2 = 1.190$ in table XV of ref. [2]), we find a reduced L/K capture ratio of 0.128 ± 0.002. Together with the other reduced L/K capture ratio of 0.123 ± 0.003 for ^{105}Ag this gives a weighted mean reduced L/K capture ratio of 0.127.

In conclusion we have to remark that our $X^{L/K}$ value does not support Goverse's idea that correlation effects would cause systematic discrepancies between theory and experiment.

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