# $K$-electron capture probability in the decay of $^{108}Ag^m$ (127 yr)

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(Received 30 June 1978)

The $K$-electron capture probability ($P_k$) in the decay of $^{108}Ag^m$ (127 yr) has been determined from a measurement of the Pd $K$ x-ray intensities as well as from the analysis of the $K$ x-ray gamma-ray sum peak. From the measured value of $P_k$ ($0.85 \pm 0.04$) the ground-state mass difference between $^{108}Ag$ and $^{108}Pd$ is estimated as $Q^+ = 1926^{+\infty}_{-169}$ keV.

[RADIOACTIVITY $^{108}Ag^m$: measured $I_\gamma$, $I_{Kx}$, sum peak area; deduced $P_K$, $Q^+$.]

The importance of electron capture probabilities in nuclear decay is well known. Recently, Bambynek *et al.*[1] have reviewed experimental data on electron capture probabilities and have emphasized the need for additional data. Although the decay scheme of $^{108}Ag^m$(127 yr) is well established, the electron-capture probabilities in this decay have not been thoroughly investigated.[2] So far, to our knowledge, the only measurement of the $K$-electron capture probability ($P_K$) is from $K$ x-ray gamma-ray coincidences measured with a NaI(Tl) detector and a proportional counter.[3]

We have successfully used high-resolution Ge(Li) detectors for the determination of $P_K$ in a number of nuclear decays.[4-6] Since the decay scheme of $^{108}Ag^m$ is simple, we felt that $P_K$ could also be determined in this manner. We have determined $P_K$ (i) from the measurement of the Pd $K$ x rays and (ii) from a measurement of the area under the $K$ x-ray gamma-ray sum peak. The determination of $P_K$ by either of these two methods or the coincidence method mentioned above requires knowledge of $\omega_K$, the $K$ fluorescence yield, and $\epsilon_{Kx}$, the absolute efficiency for $K$ x rays. While $\omega_K$ can be taken from the literature, $\epsilon_{Kx}$ usually requires a separate measurement for which an identical geometrical configuration is very difficult to achieve. For $^{108}Ag^m$, $\omega_K$ and $\epsilon_{Kx}$ were determined from a simultaneous measurement of the Ag $K$ x rays arising from the conversion of the isomeric transition (Fig. 1).

The $^{108}Ag^m$ source used in the present work was ~16 years old and free from impurities. Figure 2 shows a typical spectrum obtained with a high-resolution (500 eV) Ge(Li) x-ray detector (4.88-mm deep by 10-mm diameter) in a close-geometry configuration.

The $K$ conversion coefficients of the 434.0-, 614.4-, and 722.9-keV $\gamma$ rays are very small ($< 0.0008$),[2] therefore the Pd $K$ x rays observed in the decay were attributed to the $K$ capture only. The area under the Pd $K\alpha$ peak is therefore

$$N_{PdK\alpha} = N_0^{EC} P_K \omega_K f_{K\alpha} \epsilon_{K\alpha} , \quad (1)$$

where

$$f_{K\alpha} = \frac{I_{K\alpha}}{I_{K\alpha} + I_{K\beta}}$$

and $N_0^{EC}$ is the branching to the 1771.3-keV state (Fig. 1).

From the decay scheme it is apparent that the area under the Ag $K_\alpha$ peak can be written

$$N_{Ag\,K\alpha} = N_0^{IT} \left( \frac{\alpha_K^{30.4}}{1+\alpha_T^{30.4}} + \frac{\alpha_K^{79.0}}{1+\alpha_T^{79.0}} \right) \omega_K f_{K\alpha} \epsilon_{K\alpha} , \quad (2)$$

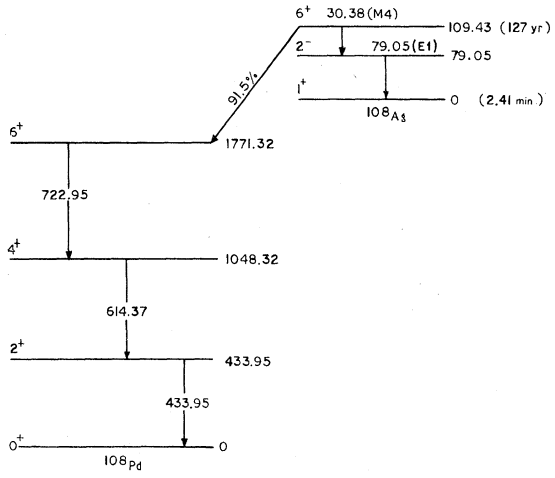
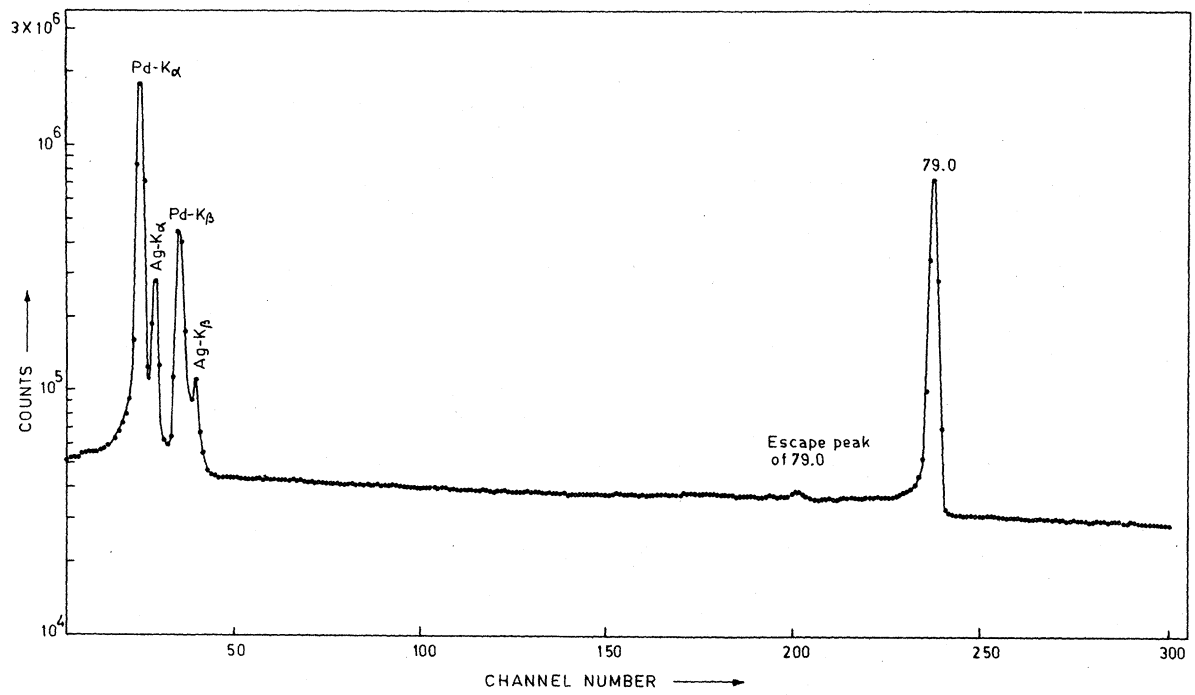



FIG. 1. The decay scheme of $^{108}Ag^m$ (127 yr) from Nuclear Data Sheets (Ref. 2).



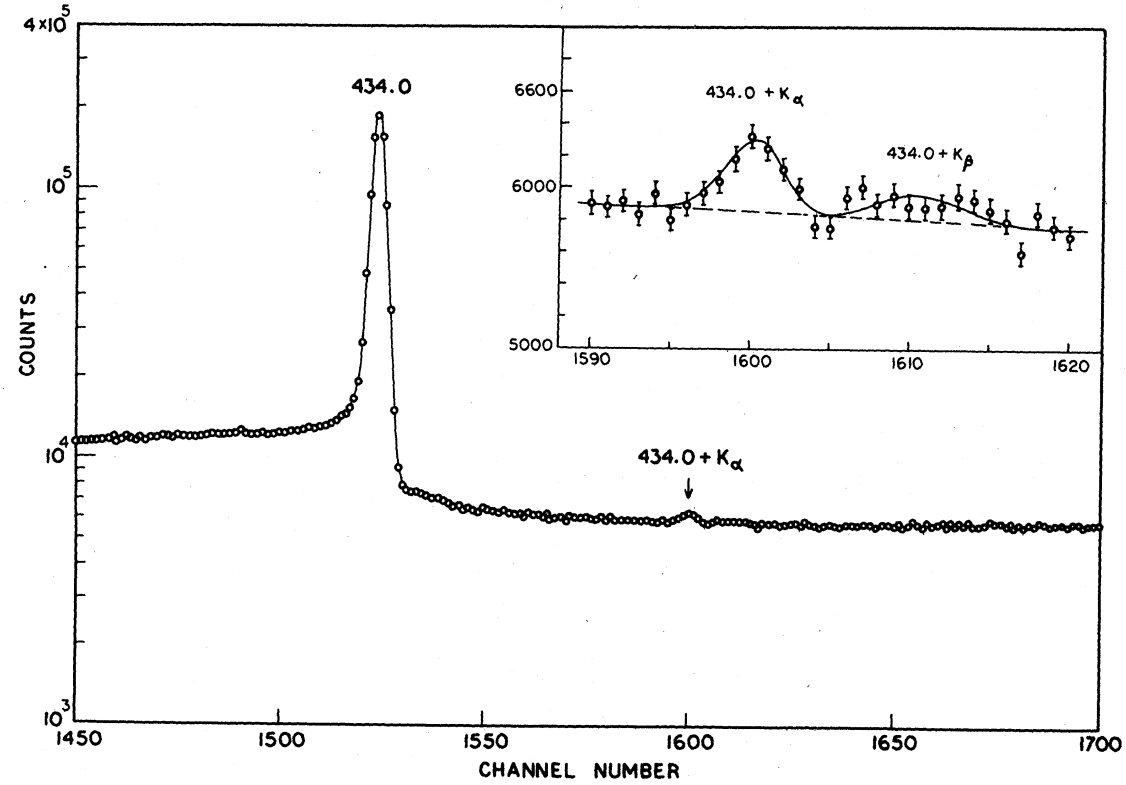




FIG. 2. A typical gamma-ray spectrum of $^{108}Ag^{m}$ obtained with a 4.88-mm deep and 10-mm diameter Ge(Li) x-ray detector with the source at 2-mm distance from the Be-window of the detector.

where $N_0^{IT}$ is the branching to the isomeric transition. Equation (1) can be simplified with the aid of Eq. (2):

$$P_K = \frac{8.5}{91.5}\frac{N_{\mathrm{Pd}\,K\alpha}}{N_{\mathrm{Ag}\,K\alpha}}\left(\frac{\alpha_K^{30.4}}{1+\alpha_T^{30.4}}+\frac{\alpha_K^{79.0}}{1+\alpha_T^{79.0}}\right), \tag{3}$$

where the adopted value of the branching ratio[2] has been used. The conversion coefficients of the 30.4- and 79.0-keV $\gamma$ rays correspond to $M4$ and $E1$ transitions, respectively.[2,7] The calculated conversion coefficients of Hager and Seltzer[8] were used.

Because of its low specific activity, the Ag source had to be rather thick (70 mg/cm$^2$). The external conversion of the 79.0-keV $\gamma$ ray in the source could therefore not be neglected. A correction was applied to the area of the Ag $K\alpha$ peak that enters in Eq. (2), using the mass absorption coefficients given by Storm and Israel.[9] Furthermore, since Eq. (2) gives the value of $\omega_K f_{K\alpha}\epsilon_{K\alpha}$ for Ag a small correction is necessary for its use for Pd in Eq. (1). This was made using the efficiency curve,[4] the fluorescence yields from Bambynek *et al.*,[10] $I_{K\beta}/I_{K\alpha}$ ratios from Hansen, Freund, and Fink,[11] and absorption coefficients from Storm and Israel.[9] With these corrections, Eq. (3) yields $P_K = 0.85 \pm 0.04$. The details of the measurement of $P_K$ from the $K$ x-ray $\gamma$-ray sum peaks have been described by Dasmahapatra and Mukherjee.[4] Because of the rapid fall of efficiency with energy,[4] out of three $K$ x-ray $\gamma$-ray sum peaks expected from the decay scheme, only the (434.0-keV $+K\alpha$) and (434.0-keV $+K\beta$) sum peaks were observed (Fig. 2). We determined $P_K$ from the (434.0-keV $+K\alpha$) sum peak, using the expression

$$P_K = \frac{N^{\mathrm{sum}}_{434.0+K\alpha}}{N_{434.0}}\,\frac{1}{\omega_K f_{K\alpha}\epsilon_{K\alpha}}\,. \tag{4}$$

For the determination of $\omega_K f_{K\alpha}\epsilon_{K\alpha}$ from Eq. (2), the source strength $N_0$ was measured with a 32.2-cm$^3$ Ge(Li) detector using the sum technique. Since the 434.0-, 614.4-, and 722.9-keV $\gamma$ rays are in cascade, one observes three $\gamma$-$\gamma$ sum peaks in a close-geometry configuration.[12] Consequently, $N_0^{\mathrm{EC}}$ can be determined from the three sum peaks independently. For example, using the (434.0 +614.4)-keV sum peak, $N_0^{\mathrm{EC}}$ can be expressed as

$$N_0^{\mathrm{EC}} = \frac{N_{434.0}\times N_{614.4}}{N^{\mathrm{sum}}_{434.0+614.4}}\,, \tag{5}$$

where the areas of the photopeaks $N_{434.0}$ and $N_{614.4}$ are corrected for summing using known peak-to-total ratios of the detector. The weighted average of $N_0^{\mathrm{EC}}$ determined from the three sum peaks yields $N_0^{\mathrm{EC}} = 0.254 \pm 0.004$ $\mu$C. With this value of $N_0^{\mathrm{EC}}$ and the corrections mentioned above, we find $\omega_K f_{K\alpha}\epsilon_{K\alpha} = 0.00310 \pm 0.00015$. From Eq. (4), we find $P_K = 0.83 \pm 0.13$. This value of $P_K$ agrees well with that measured from the Pd $K$ x-ray intensity. The relatively large uncertainty in the result from this method is due to the poor statistics of the sum peak (Fig. 2).

From the weighted average of the two values of $P_K$ as determined above, we find $P_K = 0.85 \pm 0.04$. This value of $P_K$ is in good agreement with $P_K = 0.84 \pm 0.04$ obtained by Kistner and Sunyar[3] using a different method. It should, however, be noted that the latter value of $P_K$ will change to 0.81 if, instead of $\omega_K = 0.79$, the recent value ($\omega_K = 0.82 \pm 0.03$) of Bambynek *et al.*[11] is used.

The relation between the electron-capture decay energy $Q_{\mathrm{EC}}$ and $P_K$ for allowed decay[13] is

$$Q_{\mathrm{EC}} = \frac{E_{L_1} - kE_K}{1-k}\,, \tag{6}$$

where

$$k = \left[\frac{(1-P_K)/P_K}{\frac{B_{L_1}}{B_K}\frac{g_{L_1}^2}{g_K^2}\left(1+\frac{B_{L_2}}{B_{L_1}}\frac{f_{L_2}^2}{g_{L_1}^2}+\frac{P_{MN\ldots}}{P_{L_1}}\right)}\right]^{1/2},$$

$E_K$ and $E_{L_1}$ are the $K$- and $L_1$-shell binding energies of Pd, $g$ and $f$ are the electron radial wave functions of the respective shells evaluated at the origin, $B_K$, $B_{L_1}$, and $B_{L_2}$ are the exchange correction factors for the respective shells introduced by Bahcall,[15] and $P_{MN\ldots}/P_{L_1}$ is the correction for capture from higher shells.

From the value of $P_K$ (0.85 ± 0.04) obtained in the present work, we find $Q_{\mathrm{EC}} = 264^{+\infty}_{-169}$ keV. From the decay scheme (Fig. 1), the ground-state mass difference between $^{108}$Ag and $^{108}$Pd is therefore $Q^+ = 1926^{+\infty}_{-169}$ keV. In view of the nature of the $Q_{\mathrm{EC}} - P_K$ curve, the upper limit of $Q^+$ is not determinable from the measurement of $P_K$. Considering the lower limit, we find that the value obtained here is in good agreement with $Q^+ = 1901 \pm 25$ keV obtained by Frevert from the measurement of the positron end-point energy in the decay of $^{108}$Ag (2.42 m). The present measurement also agrees with the adopted value of 1921 ± 8 keV[2] evaluated from mass adjustments by Wapstra and Gove.[16]

We further note that the measured $Q_{\mathrm{EC}} \cong 264$ keV, together with the half-life of 127 yr, gives $\log ft \approx 9$. Since the spin of $^{108}$Ag isomeric state is assumed to be $6^+$ and the spin of the level fed by $K$ capture is known as $6^+$, the EC transition is allowed. Therefore, $\log ft \approx 9$ for such a transition is impossible, This inconsistency suggests that either the spin assignment of $6^+$ for the $^{108}$Ag isomeric state is wrong or the decay energy measured here is not correct. We suggest a detailed study of the level scheme of $^{108}$Ag$^m$ to resolve this difficulty.

The authors would like to thank Professor S. K. Mukherjee and Professor A. P. Patro for providing the experimental facilities and Professor S. B. Karmohapatro for providing the $^{108}Ag^{m}$ source. One of them (B. K. D.) thanks Professor R. L. Sengupta, Professor S. C. Chakravarty, and Dr. D. Sen of the University of Burdwan for their encouragement and interest in the work.

[1]W. Bambynek *et al.*, Rev. Mod. Phys. 49, 77 (1977).
[2]Nuclear Data Sheets B7, No. 1 (1972) .
[3]O. C. Kistner and A. W. Sunyar, Phys. Rev. 143, 918 (1966).
[4]B. K. Dasmahapatra and P. Mukherjee, J. Phys. A 7, 388 (1974).
[5]B. K. Dasmahapatra, Phys. Rev. C 12, 702 (1975).
[6]B. K. Dasmahapatra, Pramana 4, 218 (1975).
[7]W.-D. Schmidt-Ott and R. W. Fink, Z. Phys. 254, 281 (1972).
[8]R. S. Hager and E. C. Seltzer, Nucl. Data A4, No. 1–2 (1968).
[9]E. Storm and H. I. Israel, Nucl. Data A7, 565 (1970).
[10]W. Bambynek *et al.*, Rev. Mod. Phys. 44, 716 (1972).
[11]J. S. Hansen, H. U. Freund, and R. W. Fink, Nucl. Phys. A142, 604 (1970).
[12]B.K. Dasmahapatra and P. Mukherjee, Nucl. Instrum. Methods 107, 611 (1973).
[13]M. J. Martin and P. H. Blichert-Toft, Nucl. Data A8, No. 1–2 (1970).
[14]L. Frevert, Z. Phys. 169, 456 (1962).
[15]J. N. Bahcall, Phys. Rev. 132, 362 (1963).
[16]A. H. Wapstra and N. B. Gove, Nucl. Data A9, No. 4–5 (1971).