$L_{\rm I}$, $L_{\rm II}$, $L_{\rm III}$, and M Internal Conversion Lines of the 411.8-kev Transition in Hg^{198}

D. Reitmann, H. Schneider, and I. J. van Heerden
Nuclear Physics Division of the National Physical Research Laboratory, Council for Scientific and Industrial Research, Pretoria, South Africa
(Received February 6, 1958)

The $L_{\rm I}$:$L_{\rm II}$:$L_{\rm III}$:M internal conversion ratios for the 411.8-kev γ-ray transition in Hg^{198} were measured and compared with the theoretical $E2$ values. The results indicate that the finite nuclear size effect, if present, is small.

Although the 2.69-day activity of Au^{198} is one of the best known β transitions, the $L_{\rm I}$ and $L_{\rm II}$ internal conversion lines of the subsequent 411.8-kev γ ray have not yet been totally resolved.[1,2] The $E2$ character of this transition has been confirmed by different methods.[3,4] In the present investigation the $L_{\rm I}$:$L_{\rm II}$:$L_{\rm III}$:M ratios have been determined and compared with the theoretical $E2$ values, in an attempt to decide whether the finite nuclear size has any effect on the internal conversion of $E2$ transitions.

For improved resolving power of a β spectrograph more sensitive detection methods and sources with higher specific activities are required. The following method has therefore been used:

A 5-mg sample of spectroscopically pure Au^{197} was irradiated for two weeks in the Harwell pile at maximum available flux, and a specific activity of about 10 mC/mg was obtained. The sample was then dissolved in hot aqua regia, evaporated to dryness, taken up in water, and finally deposited by electrolysis on a tungsten wire 25 μ thick. A 20-μ thick source was obtained and was confined to the front side of the wire by a thin layer of SiO which had been evaporated on to the other side.

Freshly poured Ilford G5 emulsion, 100 μ thick, was used as detector, and the individual electron tracks counted on a Cooke, Troughton, and Simms M4000 microscope at a magnification of about 2000. As shown by Antonova,[5] this method eliminates the correction for the energy sensitivity of the detector, and also permits the use of sources much weaker (and hence thinner) than is required with other methods. A conventional 180° permanent-magnet β spectrograph as described by Slätis[6] was used. In this instrument the emulsion makes an angle of about 20° with the plane of incidence of the electrons, sufficient to make detection of the tracks relatively easy. Up to 50 tracks per field of view ($50\,\mu\times50\,\mu$) could be counted reliably.

Figure 1 shows the results obtained with a 20-hour exposure to the Au^{198} source. Each point represents the sum of 15 adjacent scans along the length of the emulsion plate. Statistical errors are indicated. Investigation of the β spectrum and the Fermi-Kurie plot showed that the transmission correction over this small spectral region was much smaller than the statistical errors and could therefore be neglected. The following values for

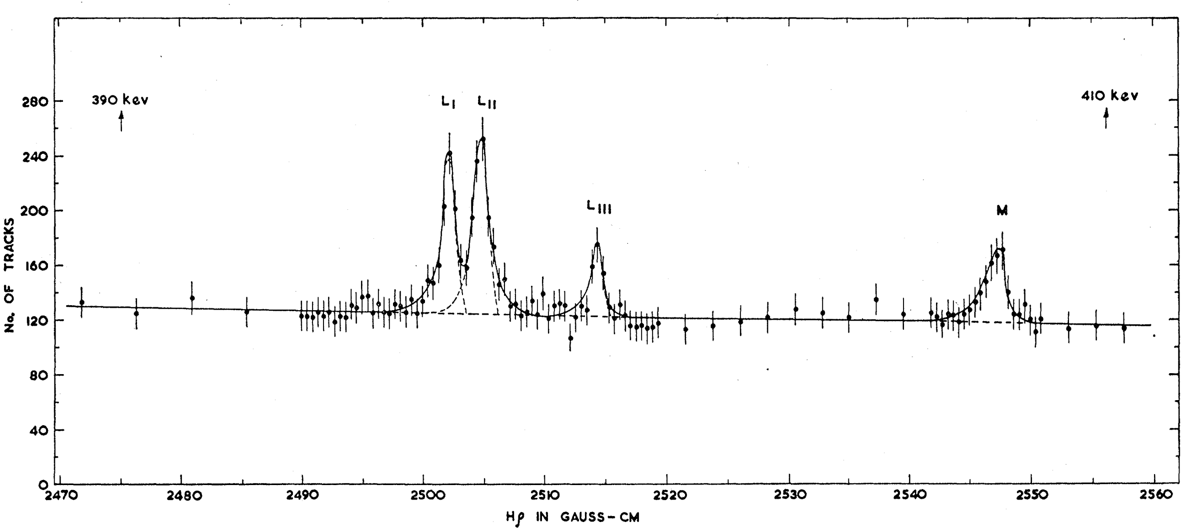

FIG. 1. $L_{\rm I}$, $L_{\rm II}$, $L_{\rm III}$, and M internal conversion lines in Hg.[198]

[1] Birkhoff, Smith, Hubbell, and Cheka, Rev. Sci. Instr. **26**, 959 (1955).
[2] Connors, Miller, and Waldman, Phys. Rev. **102**, 1584 (1956).
[3] F. R. Metzger, Phys. Rev. **97**, 1258 (1955).
[4] A. W. Sunyar, Phys. Rev. **98**, 653 (1955).
[5] I. A. Antonova, J. Exptl. Theoret. Phys. S.S.S.R. **30**, 571 (1956) [translation: Soviet Phys. JETP **3**, 461 (1956)].
[6] H. Slätis, Arkiv Fysik **6**, 415 (1953).

the relative conversion coefficients were obtained:

$$L_{\mathrm{I}}:L_{\mathrm{II}}:L_{\mathrm{III}}=(2.51\pm0.24):(3.12\pm0.28):(1.00\pm0.11).$$

Our values for $(L_{\mathrm{I}}+L_{\mathrm{II}})/L_{\mathrm{III}}$ and L/M, respectively, are 5.63 ± 0.35 and 3.67 ± 0.25, and agree very well with the ratios found by Birkhoff *et al.*,[1] *viz.*, 5.9 and 3.61. However, the theoretical values obtained by interpolation from the tables of Rose[7] are

$$L_{\mathrm{I}}:L_{\mathrm{II}}:L_{\mathrm{III}}=2.23:2.45:1.00.$$

The seemingly large values for L_{I} and L_{II} relative to L_{III} may in part be attributed to the statistical uncertainty in the measurement of the latter. At present it is expected that the effect of finite nuclear size would be small for an $E2$ transition, and should decrease the $L_{\mathrm{I}}/L_{\mathrm{III}}$ and $L_{\mathrm{II}}/L_{\mathrm{III}}$ ratios.[8,9] Our results may therefore be an indication that this effect, if present, is small.

ACKNOWLEDGMENTS

The authors would like to thank Dr. S. J. du Toit, head of the Nuclear Physics Division for his interest in this work, and the South African Council for Scientific and Industrial Research for permission to publish this article. One of us (D.R.) would also like to thank the South African Board of Atomic Energy for a research scholarship.

[7] M. E. Rose (privately distributed tables).

[8] M. E. Rose (private communication).

[9] K. W. Ford (private communication).

PHYSICAL REVIEW VOLUME 110, NUMBER 5 JUNE 1, 1958

Lifetime of the 6.14-Mev 3^- State of O^{16} by a Recoil Method*†

D. KOHLER AND H. H. HILTON
Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California

(Received February 5, 1958)

The lifetime of the 6.14-Mev 3^- state of O^{16} has been measured by means of a recoil technique. The spatial distribution of decays of recoiling O^{16} nuclei, produced by the reaction $F^{19}(p,\alpha_1)O^{16*}$, was studied with a highly collimated γ-ray detector. Comparison with the corresponding distribution obtained when the O^{16} nuclei were stopped at the target surface by an evaporated metallic layer provided a means of determining the lifetime. A value for this half-life of $(8.6\pm4.0)\times10^{-12}$ second [mean life, $\tau=(1.2\pm0.6)\times10^{-11}$ sec] has been found, consistent with previously established limits. The measured value is compared with values predicted from various nuclear models.

I. INTRODUCTION

PREVIOUS investigations[1,2] had established an upper limit to the lifetime of the 6.14-Mev 3^- state of O^{16} by use of the recoil technique.[3] As used here, the expression recoil technique refers to a method of measuring the lifetime of an excited state by employing the motion of the recoiling nuclei to convert times of decay to corresponding positions of decay, the latter being studied by an appropriately collimated detector. In addition a lower limit to the lifetime had been established by the Doppler-shift technique.[1] These two limits together give for the half-life, $t_{\frac{1}{2}}$, the range: $5\times10^{-12}\ \mathrm{sec}\leqslant t_{\frac{1}{2}}\leqslant 10\times10^{-12}$ sec.

Previous attempts in this laboratory to measure the O^{16*} lifetime demonstrated the necessity of having the target on a thick backing, since thin foils, necessary for looking at the forward recoils, fluttered sufficiently under bombardment to mask the effect of a short lifetime. Similarly, evaporated metallic layers to stop the recoils were found necessary, as no dependable method of cementing foils onto the target without subsequent blistering under bombardment was found. The present experiment was therefore designed[4] to use a target evaporated onto a rigid metal backing, the decay of the recoils in the backward hemisphere then being studied for evidence of an effect due to a small but nonzero lifetime. The evaporated metallic layer which stopped the recoils was used to provide an effective calibration of the apparatus. With these improvements in the target arrangement and with further improvements in collimation, it was felt that the technique could be used to measure lifetimes down to the order of a few times 10^{-12} second.

II. EXPERIMENTAL APPARATUS AND PROCEDURE

The apparatus, shown in Fig. 1, consisted in part of a thick brass target block mounted on the end of a differentially threaded shaft, by means of which the

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

† A brief report of this experiment together with a preliminary value of the lifetime was given at the Monterey Meeting of the American Physical Society, December 27–29, 1956 [Bull. Am. Phys. Soc. Ser. II, 1, 390 (1956)].

[1] Devons, Manning, and Bunbury, Proc. Phys. Soc. (London) A68, 18 (1955).

[2] C. A. Barnes and J. Thirion, 1955 (private communication).

[3] J. Thirion and V. Telegdi, Phys. Rev. 92, 1253 (1953). This article contains references to earlier lifetime work by the recoil method.

[4] These modifications were suggested by C. A. Barnes.