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Lifetime of the 11-keV Level in Cs^{134}†

F. J. LYNCH AND L. E. GLENDENIN
Argonne National Laboratory, Argonne, Illinois 60439
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The mean life of the 11-keV level following the decay of Cs^{134m} has been measured by a delayed-coincidence technique and found to be 69±1 nsec. An indirect measurement of the total-internal-conversion coefficient for this transition ($\alpha=105$) agrees closely with the theoretical value for a pure $M1$ transition. This implies that the mean life for radiative decay is $\tau_0=7314$ nsec. This is about 1.8 times the radiative mean life calculated with the odd-group model with the aid of the magnetic moments of neighboring nuclei.

INTRODUCTION

It was shown by Sunyar *et al.*[1] that the 2.9-h metastable state in Cs^{134} decays via a 127-keV transition followed by a 10.4-keV transition with a half-life they estimated to be <100 nsec. The present work was undertaken primarily to measure the lifetime of the first excited state at 11 keV which, according to them, decays by magnetic-dipole transition. In order to obtain the mean life for radiative decay from the experimental mean life, the total-internal-conversion coefficient was measured. A byproduct of this latter measurement was a more accurate determination of the energies of the two γ rays.

EXPERIMENTAL

A. Lifetime of the 11-keV Level

The 2.9-h metastable state in Cs^{134} was produced by neutron irradiation of a CsF sample. The 127-keV γ ray accompanying the formation of the 11-keV level was detected in a NaI(Tl) scintillator measuring 0.250 in. long by 1.0 in. o.d. and mounted on an RCA-8575 photomultiplier. The 11-keV γ ray and 4.5-keV L x rays were detected in a NaI(Tl) scintillator, which was 0.020 in. long by 1.0 in. o.d., was provided with a 0.020-in. Be window, and was mounted on an RCA C-31000D photomultiplier (which is the same as the RCA-8575 except for a special high-gain first dynode). Figure 1 shows the pulse-height spectra obtained with the two scintillation detectors and indicates the positions of the windows of the single-channel analyzer (SCA) in the two channels. Pulses from the time-to-amplitude converter (TAC) were stored in the multichannel analyzers only if they were associated with pulses from both detectors and if the amplitudes of these pulses satisfied the pulse-height requirements in their respective channels. The probability distribution of the differences in time between the detection of the 127-keV γ ray and the 11-keV γ ray or L x ray is shown in Fig. 2, which also shows the response of the system to simultaneous γ rays from the annihilation of positrons. The latter data were taken by merely substituting a Na^{22} source for the Cs^{134} source.

Time calibration was made by use of the method of accidental coincidence. This is based on the fact that the accidental coincidence rate obtained with two uncorrelated input pulses to the TAC depends on the product of the pulse rates and the width of each time channel. That is,

$$N_i = Nf\Delta t_i,$$

where N_i is the number of counts in channel i, N is the number of effectual stop pulses (those arriving when the multichannel analyzer is not busy and having amplitudes that satisfy the window requirement of the SCA in the stop channel), f is the frequency of the crystal-controlled pulse generator that provides the start pulses, and Δt_i is the width of each time channel. The resultant "random time spectrum" also provides information for correcting for nonlinearities in the time-measuring system.

After correcting the data for the slight nonlinearity in the time scale, the mean life was calculated by least-squares fitting a straight line to the tail of the distribution shown in Fig. 2. The weighted mean for three measurements was 69.0±0.33 nsec; and when an estimate of all errors was included, the figure became 69±1 nsec. As a check on the technique, the mean life of the 14.4-keV level in Fe^{57} was measured by simply substituting a Co^{57} source for the Cs^{134m} source. The results gave $T_{1/2}=97.7$ nsec, in close agreement with the accepted value,[2] 98 nsec.

B. Energy Measurements

The energy of the γ rays from Cs^{134m} was determined from the pulse-height spectrum (PHS) obtained with a cooled Si(Li) detector. Figure 3 shows the PHS ($E_\gamma<40$ keV) obtained with a combined Cs^{134m} and Co^{57} source. The 11.23-keV γ ray of Cs^{134} is bracketed by the 14.39-keV γ ray of Fe^{57} and the 6.4-keV K x ray of Fe. In a higher-energy range (not shown), the 127.37-keV γ ray of Cs^{134} is bracketed by the 121.93- and 136.22-keV γ rays of Fe^{57}. Comparison with these well-known Fe lines gave $E_1=11.23\pm0.1$ keV and $E_{3-1}=127.37\pm0.2$ keV; and this would imply that the energy E_3 of the third excited state is 138.6 keV. No photopeak was observed at 138.6 keV, where the cross-over transition to the ground state would be expected. The values

† Work performed under the auspices of the U.S. Atomic Energy Commission.
[1] A. W. Sunyar, J. W. Mihelich, and M. Goldhaber, Phys. Rev. **95**, 570 (1954).
[2] O. C. Kistner and A. W. Sunyar, Phys. Rev. **139**, B295 (1965).

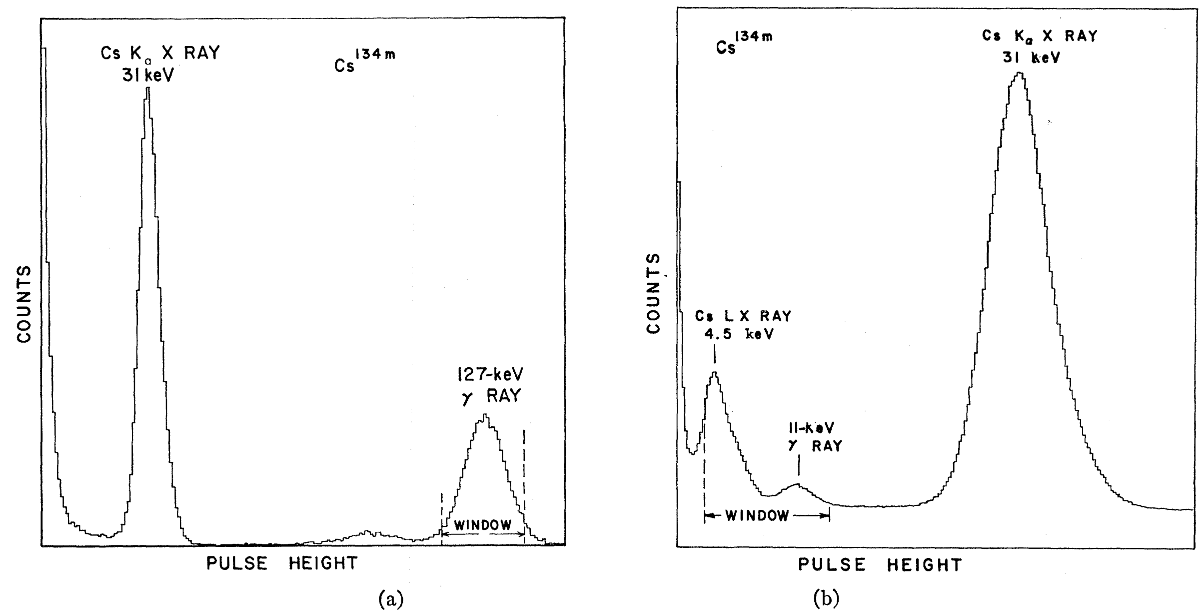

FIG. 1. PHS of Cs^{134m}, showing the window positions of the SCA. (a) Spectrum taken with an NaI(Tl) scintillator 0.250 in. long by 1 in. o.d. (b) Spectrum taken with a similar scintillator provided with a 0.020-in. Be window and mounted on the RCA C31000D photomultiplier.

previously reported by Sunyar *et al.*[1] are $E_1=10.3\pm0.4$ keV, $E_{3-1}=127.1\pm0.5$ keV, $E_3=137.4\pm0.5$ keV. Mihelich[3] measured $E_{3-1}=127.6$ keV.

C. Internal-Conversion Coefficient of the 11.3-keV Transition

Because the efficiency of detection of photons at energies below 8 keV was low and unknown, the total-internal-conversion coefficient of the 11.23-keV transition was estimated from the ratio of the intensity of the 127-keV γ rays to that of the 11-keV γ rays and the previously published[4] ratio of the total number of disintegrations to the number of 127-keV γ rays, namely, dis/$\gamma=7.0\pm0.2$. The resulting total-internal-conversion coefficient for the 11-keV level is 104.74 ± 7. This agrees closely with the theoretical value 105 calculated by Hager and Seltzer[5] for a pure $M1$ transition.

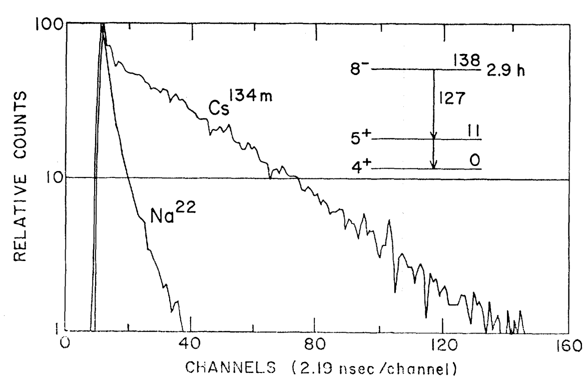

FIG. 2. The probability distribution of the delay times of the 11-keV γ rays and L x rays relative to the 127-keV γ ray from Cs^{134m}.

D. Estimated Mean Life

It is interesting to compare the experimental value of the mean life with that previously estimated by Kurath[6] from the odd-group model. This model, originally introduced by Schwartz,[7] estimates $M1$ matrix elements on the basis of the observed magnetic moments of nearby odd-A nuclei. If the 4^+ ground state and 5^+ excited state are both assumed to arise from coupling a $\frac{7}{2}$ proton group to a $\frac{3}{2}$ neutron group, the magnetic moments are given by

$$\mu(5^+)=\mu(\tfrac{7}{2}^+, p)+\mu(\tfrac{3}{2}^+, n), \qquad (1)$$

$$\mu(4^+)=0.9143\mu(\tfrac{7}{2}^+, p)+0.533\mu(\tfrac{3}{2}^+, n). \qquad (2)$$

The measured magnetic moments of the $\frac{7}{2}^+$ proton group are 2.579 μ_N in Cs^{133} and 2.729 μ_N in Cs^{135}, while that of the $\frac{3}{2}^+$ neutron group is 0.837 μ_N in Ba^{135}. If we use the average values $\mu(\frac{7}{2}^+, p)=2.654$ and $\mu(\frac{3}{2}^+, n)=0.837$ μ_N, then from Eq. (1) we obtain

$$\mu(5^+)=3.490\ \mu_N,$$

and from Eq. (2) we obtain

$$\mu(4^+)=2.873\ \mu_N.$$

[3] J. W. Mihelich, Phys. Rev. **87,** 646 (1952).
[4] B. Keisch and E. A. C. Yates, J. Inorg. Nucl. Chem. **17,** 183 (1961).
[5] R. S. Hager and E. C. Seltzer. Nucl. Data **A4,** 90 (1968).
[6] D. Kurath (private communication).
[7] C. Schwartz, Phys. Rev. **94,** 95 (1954).

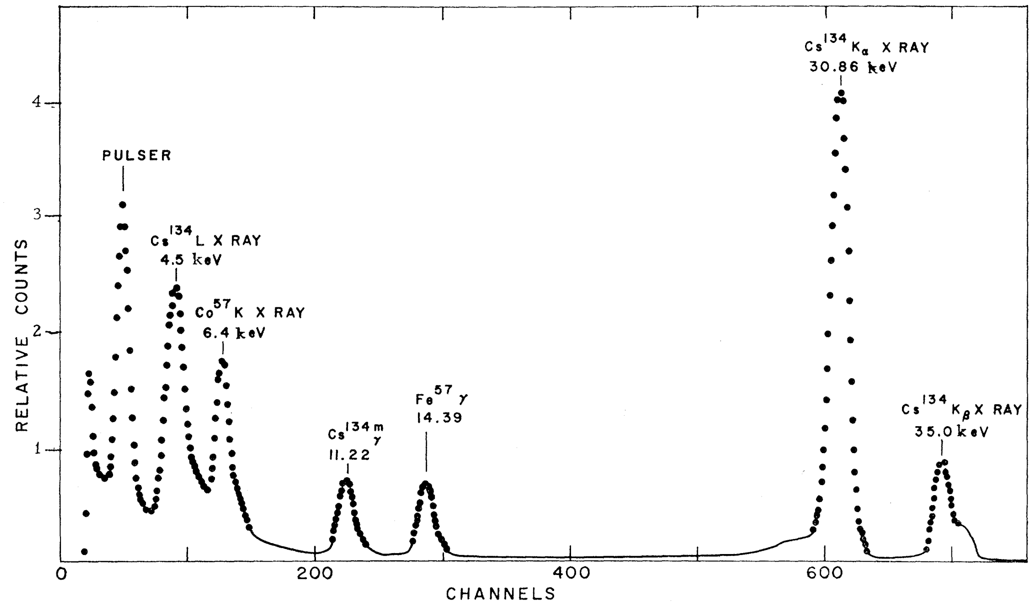

FIG. 3. PHS of Cs^{134m} and Co^{57}, taken with a 3-mm lithium-drifted silicon detector with a 0.010-in. Be window for energies below 40 keV.

The measured value $\mu(4^+)=2.990\ \mu_N$ is in fairly good agreement with the latter.

The reduced transition probability is

$$B_{M1}(5^+\rightarrow 4^+)$$
$$=(3/4\pi)[0.2928\mu(\tfrac{7}{2}^+, p)-0.6831\mu(\tfrac{3}{2}^+, n)]^2,$$

which, because of cancellation between the two contributions, gives the very small value

$$B_{M1}(5^+\rightarrow 4^+)=1.005\times 10^{-2}\ \mu_N^2.$$

This corresponds to a radiative mean life $\tau_0=4040$ nsec, while the measured value is 7314 nsec. Considering the strong cancellation in the calculation, the agreement is fairly good.

ACKNOWLEDGMENTS

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