Half-Lives of the Excited States of ^{46}Ti, ^{84}Rb, ^{99}Tc, ^{162}Dy, ^{164}Er, and ^{196}Au

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The half-lives of the excited states of some nuclei have been measured by using the delayed-coincidence method. Upper or lower limits on half-lives are obtained in a few cases. The results are as follows:

Nucleus	Level (keV)	Half-life (sec)
^{84}Rb	250	$(3.08\pm0.55)\times10^{-10}$
^{99}Tc	181	$(3.40\pm0.10)\times10^{-9}$
^{162}Dy	1148	$(2.10\pm0.40)\times10^{-10}$
^{164}Er	90	$(1.52\pm0.06)\times10^{-9}$
^{46}Ti	2006	$<2\times10^{-11}$
^{99}Tc	920	$<1\times10^{-10}$
^{196}Au	85	$>4\times10^{-6}$

1. INTRODUCTION AND EXPERIMENTAL ARRANGEMENT

THE work reported here was undertaken to measure the half-lives of excited states of some nuclei for which no earlier measurements were available, and to remeasure some others in order to obtain more consistent values than the ones previously known. The apparatus used consisted of a fast-slow coincidence circuit employing a time-to-amplitude converter. A 512 channel pulse-height analyzer was used to record the gated output spectrum from the time-to-amplitude converter. A block diagram of the system is shown in Fig. 1. RCA 7850 photomultipliers coupled to suitable phosphors were employed as detectors. For detecting β rays and internal conversion electrons, a 3-mm-thick $\times$2.5-cm-diam NE-810 plastic scintillator was used and for γ rays, NE-102 plastic scintillators of various sizes, e.g., 2.5 cm diam$\times$5 cm long and 5 cm diam$\times$5 cm long, were used. When the half-life to be measured was sufficiently long, 5-cm$\times$5-cm NaI(Tl) phosphors were employed. For detection of low-energy x and γ rays, a 2-mm-thick$\times$3.75-cm-diam NaI(Tl) scintillator was used.

The time calibration was performed by introducing known differences of delays between the fast branches of

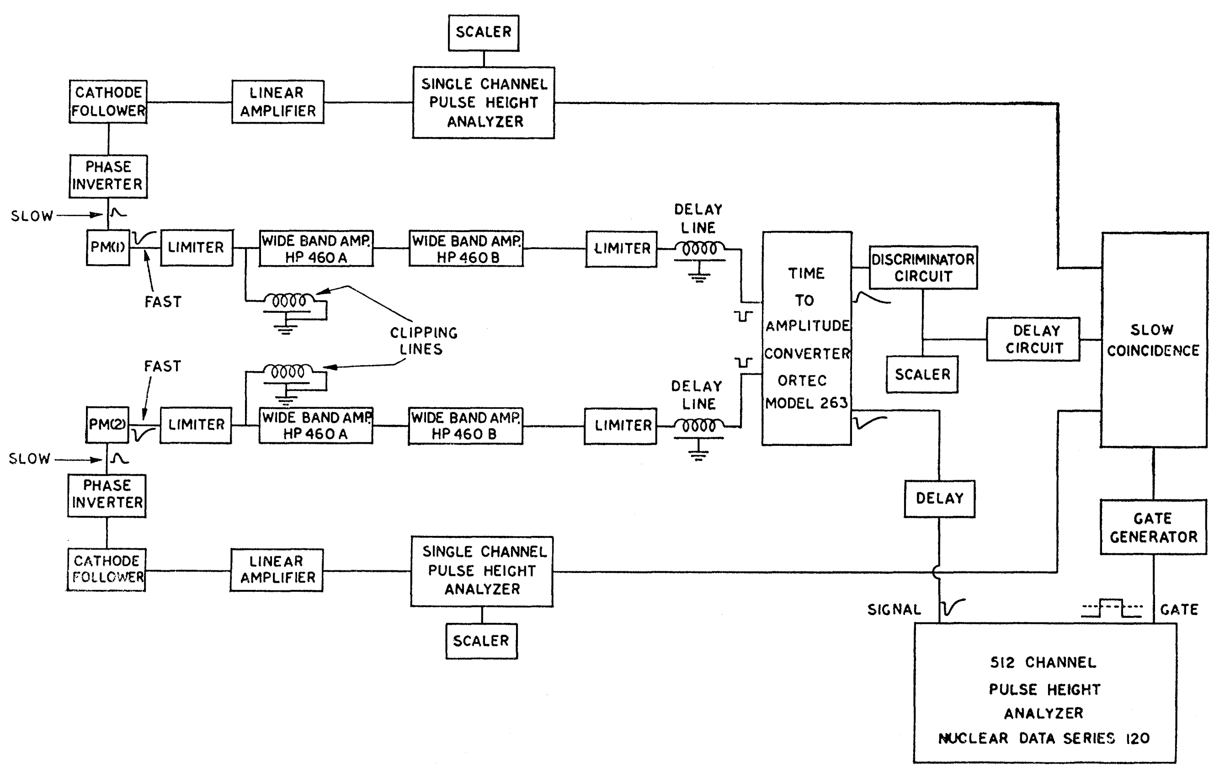

FIG. 1. Block diagram of the fast-slow coincidence arrangement. PM(1) and PM(2) are RCA-type 7850 photomultipliers.

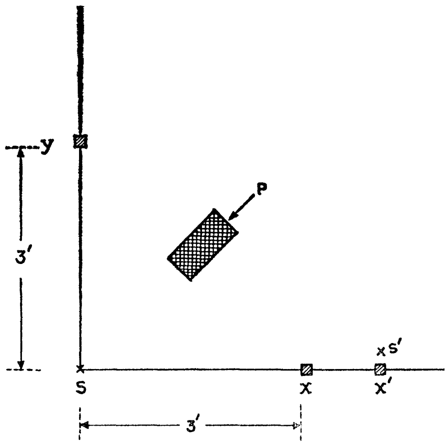

FIG. 2. The geometry used for time calibration. x and y are the initial positions of the movable and fixed counters, respectively. S is a ^{60}Co source. x' is the displaced position of the movable counter. An auxiliary ^{60}Co source S' serves to maintain the counting rate of the movable counter constant. P is a 5-in.-thick lead shield.

the system with the help of measured lengths of cables (type RG 58 A/U). In order to achieve precision in the values of delays introduced, the following procedure was adopted. The difference between lengths of two short but unequal pieces of cable was first measured accurately and then connectors were placed at the ends of each cable in an identical manner. Such a pair of cables when introduced in the fast branches of the system gave accurate difference of delays, owing to the fact that the additional small delays due to cable connectors, being identical in both cases, cancelled each other. A number of such pairs of cables prepared to introduce different time delays covered the range 0–42 nsec. The calibration graph in this range was found to be strictly a straight line. The different lengths of cables were in turn calibrated by taking the velocity of γ rays in air as the standard. The procedure adopted for this purpose consisted in using two 5-cm$\times$5-cm NE-102 plastic scintillators coupled to the RCA 7850 photomultipliers and placing them, as shown in Fig. 2, at positions x and y, at distances of 3 ft from a strong ^{60}Co source S. Of the two counters, the one at x was movable. With the counters in positions x and y a prompt curve was recorded for 20 min. Then the movable counter was shifted to the position x' by a distance of 1 ft, another ^{60}Co source S' of suitable strength placed close to it in order to keep its counting rate constant, and again a prompt curve recorded for a period of 40 min. Finally, a third prompt curve was recorded for 20 min, with the movable counter returned to its original position x and a delay introduced in the path of the fast pulse of the movable counter by means of a measured cable length. The procedure was repeated in this sequence until sufficient number of counts were recorded with each setting. The 5-in.-thick lead shield shown in Fig. 2 was employed for eliminating detector-to-detector scattering and spurious coincidences due to the source S'. The centroids of the three prompt curves were determined, and hence the delay introduced by the cable was compared with the time taken by γ rays in traversing a distance of 1 ft. Figure 3 shows such a comparison in the case of a 6-nsec cable length. The prompt curves (a) and (b) in Fig. 3 are obtained with the movable counter in positions x and x', respectively. The curve (c) corresponds to the third case when the movable counter is at x and its fast pulse is delayed by the cable. The curves of Fig. 3 were recorded by accepting pulses >600 keV from each counter. Measurement of cable delay in this way agreed within 2% with the corresponding value based on the cable parameters.

The time calibration of the apparatus in the μsec range was performed with the help of a double pulse generator having adjustable delay.

The prompt curve using ^{60}Co γ rays and 20% energy selection showed a full width at half-maximum of 6×10^{-10} sec and $T_{1/2\ \mathrm{instr}}=1.4\times10^{-10}$ sec.

The stability of the instrument was checked over long periods. No detectable shifts could be observed in 24-h intervals. Generally, measurements were completed in much shorter intervals. In the case of rapidly decaying activities, short runs were given with intervals depending on the half-lives of the sources. In such cases, the counting rate in each of the slow channels of the apparatus was recorded throughout the period of measurement, to provide a check of the variation of strength of the source. In all cases of measurement with short-lived activities reported in this work, the change of counting rate during each measurement did not produce any noticeable shifts. This fact was verified by

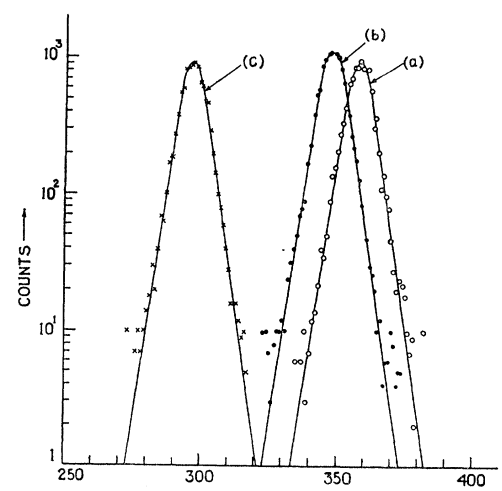

FIG. 3. The time calibration and comparison of signal velocity in the delay cables with the velocity of γ rays. The curves shown are prompt curves obtained by using the arrangement of Fig. 2. The curves (a) and (b) are recorded with the movable counter at positions x and x', respectively; x' being 1 ft away from x. Curve (c) is obtained with the movable counter at x and its fast pulse delayed by means of a 6-nsec cable length.

preparing a number of ^{60}Co sources with varying strengths and recording the prompt curve with each one of them. The delayed and prompt coincidence data, in all cases, were recorded in alternate runs in two separate sections of the memory of the multichannel analyzer. The half-life was determined from the slope of the delayed curve, wherever permissible, and also by calculating the moments of various orders for the delayed and prompt curves. The moments of orders higher than the first were defined with respect to the centroids of the experimental curves. First and second moments were used in the lifetime determination, whereas the higher-order moments were required in the evaluation of statistical errors.[1] In determining the lifetime of a particular level, a number of experiments were performed and the average of the results obtained from them was taken.

2. MEASUREMENTS AND RESULTS

A. 250-keV State of ^{84}Rb

The half-life of the 250-keV state of ^{84}Rb was determined by measuring the delay between the conversion electrons of the 216-keV transition of ^{84}Rb and the 250-keV γ rays emitted in the de-excitation of the 250-keV level. The source used was the 20-min isomer of ^{84}Rb. It was produced by $(n,2n)$ reaction with 14-MeV neutrons on natural rubidium taken in the form of rubidium nitrate. The sample was bombarded with neutrons for 30 min and the delayed-coincidence data were accumulated for the same period, followed by the recording of prompt coincidence with ^{60}Co in separate sections of memory of the multichannel analyzer. Data

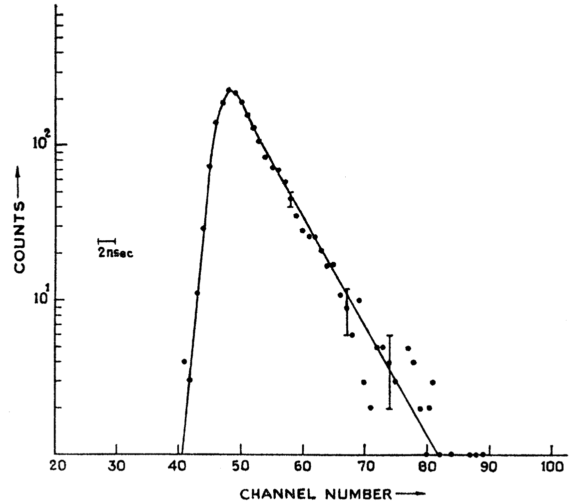

FIG. 5. The lifetime of the 181-keV level of ^{99}Tc. The delayed curve shown is obtained in a measurement of the delay of the 181-keV γ ray of ^{99}Tc with respect to the 450-keV β group of the 67-h ^{99}Mo.

from three successive irradiations were added in each experiment. A fresh sample was used for every irradiation. The electrons were detected by the 2.5-cm-diam $\times$3-mm-thick NE-810 plastic scintillator, whereas the γ rays were detected by the 2.5-cm-diam$\times$5-cm-long NE-102 plastic scintillator. The energy selection was made with sufficiently wide windows so that electrons and γ rays in the energy ranges 150–250 and 80–200 keV, respectively, were accepted. Same energy setting was used for both delayed and prompt curves. The two curves obtained from one experiment are shown in Fig. 4. The half-life of the 250-keV level was determined by moment analysis of these curves. The mean value obtained from three measurements was $(3.08\pm0.55)\times10^{-10}$ sec.

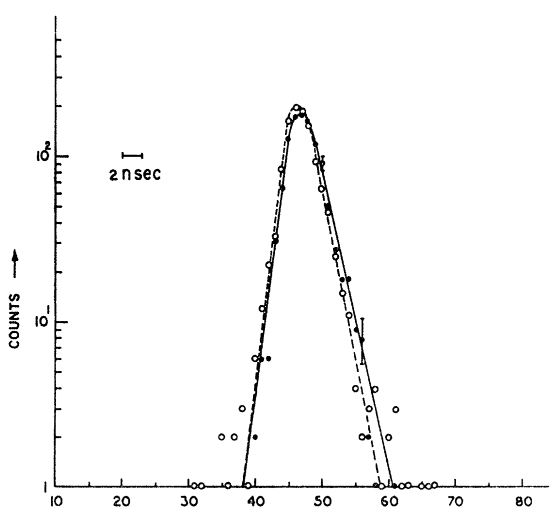

FIG. 4. Measurement of the lifetime of the 250-keV level of ^{84}Rb. The continuous line shows the delayed-coincidence curve. The prompt-coincidence curve obtained with ^{60}Co is shown by a broken line.

During each measurement the decay of the source was recorded by monitoring the count rate in the slow side channels of the apparatus. It was observed that the amount of interfering activities produced in fast neutron bombardment of natural rubidium, with half-lives longer than 20 min was such that it contributed about 4% to the singles-count rate. The coincidence counts, however, were found to be essentially due to the 20-min activity with less than 1% contribution from other activities. Therefore, no correction was needed in the delayed curve shown in Fig. 4.

The measured half-life of $(3.08\pm0.55)\times10^{-10}$ sec for the 250-keV level of ^{84}Rb shows that the 250-keV transition is hindered by a factor of 1.4×10^4 relative to the single-particle estimate, if the transition is taken to be pure $E1$. The $E1$ nature of the transition is suggested by the fact that the total conversion coefficient for this transition has been estimated to be less than 0.03.[2] The observed value of the hindrance factor is in agreement

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[2] L. Cohen, Phys. Rev. **111**, 587 (1958).

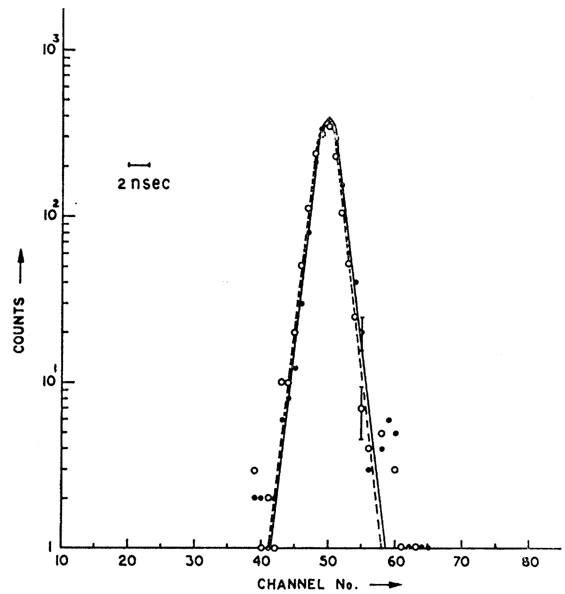

FIG. 6. The lifetime of the 1148-keV state of ^{162}Dy. The delayed- and prompt-coincidence curves are shown by closed and open circles, respectively.

with the systematic properties of the $E1$-transition probability.[3]

B. 920- and 181-keV Levels of ^{99}Tc

The 920-keV level of ^{99}Tc is populated by the 450-keV β group from the decay of ^{99}Mo. It de-excites with the emission of 780- and 740-keV γ rays. The former leads to the 6-h isomeric state of ^{99}Tc, whereas the latter populates the 181-keV level. This level also decays, giving rise to a cascade of 41- and 140-keV γ rays as well as a crossover γ ray of 181-keV energy.

The 67-h ^{99}Mo was produced by $(n,2n)$ reaction on ^{100}Mo. A sample of enriched ^{100}Mo was bombarded with 14-MeV neutrons for about 20 h. The (n,p) product ^{100}Nb, being short-lived, decays quickly, whereas the (n,α) reaction product ^{97}Zr (17 h) is produced in negligible amount because the cross section for the (n,α) reaction is about 200 times smaller than that for the $(n,2n)$ reaction.[4]

The lifetime of the 920-keV level of ^{99}Tc was estimated by detecting β particles in the thin plastic detector and the γ rays in the 1-in.-diam$\times$2-in.-long plastic detector. The energy selection in the side of the β detector was such as to allow the β particles of the 450-keV group in the energy range extending from 200–280 keV to be recorded. The energy selection in the case of the γ-ray detector covered a range 500–700 keV. With these settings, the delayed-coincidence curve was recorded. On comparison with the prompt curve recorded with the ^{60}Co source, the half-life of the 920-keV level of ^{99}Tc was found to be less than 10^{-10} sec, in agreement with the finding of Meiling *et al.*[5]

The lifetime of the 181-keV level was determined as follows. The energy selection for β rays was kept same as before. The channel setting for the γ-ray detector was shifted to the low-energy side so as to allow pulses due to 150- to 200-keV energy loss in the scintillator to be accepted. A delayed-coincidence curve was recorded (Fig. 5). With the energy setting used in this experiment, an over-all delay is expected between the 450-keV β group and the 181-keV γ ray due to the lifetimes of the 920- and 181-keV levels. From the slope of the delayed curve (Fig. 5), we get

$$T_{1/2}=3.40\pm0.10 \text{ nsec}.$$

This result is the mean of two measurements made with the above-mentioned setting. Since the half-life of the 920-keV level is found to be extremely short (<0.1 nsec), the observed half-life of 3.40±0.10 nsec is assigned to the 181-keV level. It is found that the result is consistently less than some of the values previously reported, namely, 3.5±0.3 nsec by Lehmann and Miller,[6] 3.575±0.05 nsec by Bodenstedt *et al.*,[7] and 3.59±0.05 nsec by Andrade *et al.*,[8] but agrees closely with the value of 3.45±0.06 nsec by Meiling *et al.*[5] The short lifetime of the 920-keV level also gives rise to the steeper part of the curve near the peak in Fig. 5, due to the events in which the 780- and 740-keV γ rays are detected by a 150- to 200-keV energy loss in one scintillator simultaneously with the β particles of the 450-keV group in the other scintillator. The contribution of the lifetime of the 514-keV level is negligible in this experiment, because of the extremely poor intensities of the 870-keV β group which populates this level, and the 372-keV γ ray which is emitted by the de-excitation of this level.

C. 1148-keV State of ^{162}Dy

The half-life of the 1148-keV level of ^{162}Dy was also determined from the β-γ delayed-coincidence experiment, using the same detectors as in the previous cases. The parent activity was that of ^{162}Tb (7.5 min) produced by (n,p) reaction on enriched ^{162}Dy. The $(n,2n)$ reaction product is stable, whereas the (n,α) reaction product ^{159}Gd, because of its longer half-life (18 h), is produced in negligible amount in short bombardments. The procedure was to bombard the enriched ^{162}Dy sample for 10 min, to accumulate the delayed-coincidence counts for the same interval in one section of the memory of the multichannel analyzer, and to record the prompt-coincidence counts in another section of its memory. This procedure was repeated 30 times to obtain the delayed- (points) and prompt- (circles) coincidence curves of Fig. 6. In each case the β and γ rays were

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[4] A. Chatterjee, Nucl. Phys. **47**, 511 (1963); M. Bormann, *ibid.* **65**, 257 (1965).
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[7] E. Bodenstedt, E. Matthias, and H. J. Körner, Z. Physik **153**, 423 (1959).
[8] P. D. R. Andrade *et al.*, Nucl. Phys. **66**, 545 (1965).

selected in the energy regions, 400–600 and 200–300 keV, respectively. In the decay of the 7.5 min, ^{162}Tb the most prominent β group (1450 keV, 80%) feeds the 1148-keV level of ^{162}Dy.[9] Among the γ rays emitted by de-excitation of this level, the one with the maximum intensity has the energy of 260 keV. Therefore, with the energy ranges mentioned above, 90% contribution to the delayed-coincidence counts arises due to the 1450-keV β group and the 260-keV γ ray. The prompt-coincidence curve was obtained with the help of the 82 min ^{75}Ge source produced by $(n,2n)$ reaction with 14-MeV neutrons on enriched ^{76}Ge for a few minutes. ^{75}Ge decays with the emission of a 920-keV (11.4%) β group followed by the emission of a strong 265-keV γ ray of ^{75}As. The half-life of the 265-keV level of ^{75}As is known to be 12 psec.[10] Therefore, it serves as a good standard, with reference to which the lifetime of the 1148-keV level of ^{162}Dy can be determined. The half-life of this level, obtained by moment analysis of the delayed- and prompt-coincidence data is found to be

$$T_{1/2}=(2.10\pm0.40)\times10^{-10}\text{ sec}.$$

The relative intensities of the 260-, 185-, and 1068-keV γ rays emitted in the de-excitation of the 1148-keV level are 100, 15, and 20, respectively.[9] Therefore, the partial half-life for the 260-keV transition is $(2.83\pm0.54)\times10^{-10}$ sec. It is in favor of $E1$ multipolarity for this transition.

D. 90-keV Level of ^{164}Er

The half-life of the 90-keV level of ^{164}Er was determined by a β-γ delayed-coincidence experiment. The delay was measured between the 875-keV β group emitted in the ground-state decay of ^{164}Ho and the 90-keV γ ray of ^{164}Er. The energy selection for the β and γ rays was made in the ranges 200–750 and 40–80 keV, respectively. The prompt curve was obtained with the help of the 82-min ^{75}Ge source. Keeping the above-mentioned settings for energy selection unchanged and using the ^{75}Ge source, most of the contribution to the coincidence counts was due to the 920-keV β group of ^{75}Ge and the 265-keV γ ray of ^{75}As. A relatively small contribution ($\sim$10%) was recorded due to the 980-keV β group and the 199-keV γ ray. Since the end-point energies of the β groups which produce the coincidence counts in the case of ^{164}Ho and ^{75}Ge are approximately equal, a comparison of the delayed and prompt curves is possible in spite of the fact that the β rays in either case are accepted in a broad energy range. The source ^{164m,g}Ho (39.0 and 23.9 min) was produced by ^{165}Ho$(n,2n)$ ^{164}Ho reaction with 14-MeV neutrons. A target, consisting of natural holmium, taken in the form of oxide, was irradiated with fast neutrons for 45 min. The delayed-coincidence counts were recorded 10 min after the end of the irradiation for a period of 45 min.

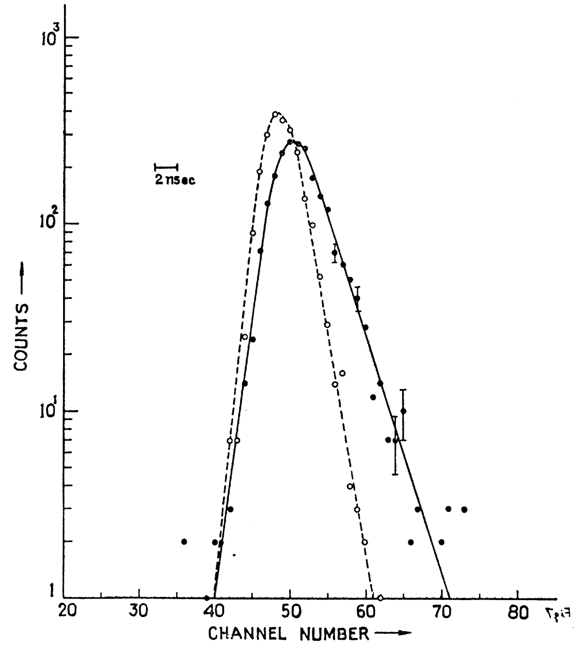

FIG. 7. Typical delayed (closed circles) and prompt (open circles) curves in the measurement of the half-life of the 90-keV level of ^{164}Er.

The 82-min ^{75}Ge for prompt coincidences was produced by bombarding enriched ^{76}Ge target with 14-MeV neutrons for 45 min. The data from three successive runs with both sources were separately added. Four such experiments were performed. The delayed- and prompt-coincidence curves obtained from one experiment are presented in Fig. 7. The decay of the singles-count rate in the selected region of the β spectrum showed that the source ^{164}Ho consisted of a transient equilibrium of its two isomeric states. The radiations emitted in the decay of the metastable state[11] do not contribute to the delayed-coincidence curve. Weak interfering activities of ^{162}Tb (7.5 min), ^{165}Dy (2.3 h), and ^{166}Ho (27 h), produced by (n,α), (n,p) and (n,γ) reactions, respectively, along with the $(n,2n)$ reaction product ^{164}Ho, in fast neutron bombardment of ^{165}Ho, do not affect the measurement. This is because the ratio of $(n,2n)$ cross section to the total cross section for reactions on ^{165}Ho at 14-MeV neutron energy is about 0.97. Further, the short-lived activity of ^{162}Tb was considerably reduced during the 10-min interval between the end of neutron bombardment and the beginning of measurement. The amounts of the 2.3-h ^{165}Dy and the 27-h ^{166}Ho activities were such that their contributions to the singles-counting rate in the β detector, within the energy region specified above, were less than or equal to 1.5 and 0.1%, respectively. Their contributions to the coincidence-counting rate were negligible. Therefore no corrections for these effects were needed in the delayed-coincidence curve shown in Fig. 7.

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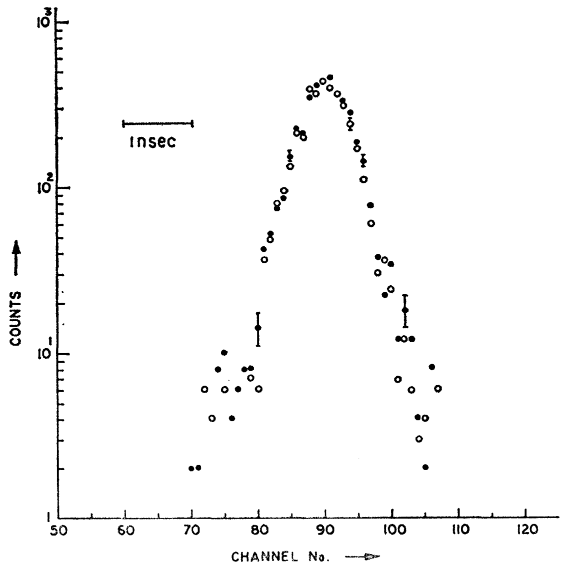

FIG. 8. Lifetime of the 2006-keV state of ^{46}Ti. Closed and open circles represent the time spectra obtained with ^{46}Sc and ^{60}Co sources, respectively.

The half-life of the 90-keV level of ^{164}Er, taking the average of four measurements, is found to be

$$T_{1/2}=(1.52\pm0.06)\times10^{-9}\text{ sec}.$$

The previously reported values of the half-life of this level by the delayed-coincidence technique are $(1.4\pm0.5)\times10^{-9}$,[12] $(1.732\pm0.003)\times10^{-9}$,[13] and $(1.43\pm0.05)\times10^{-9}$ sec;[14] our result is in agreement with the first and the last of the above-mentioned values within the error limits.

Using our measured value of the half-life and the value of $(5.04\pm0.35)e^2\times10^{-48}$ cm^4 for the reduced transition probability $B(E2;0\rightarrow2)$, reported by Elbek *et al.*,[15] the total conversion coefficient for the 90-keV transition of ^{164}Er has been calculated according to the relations given by Alder *et al.*[16] The total conversion coefficient depends sensitively on the value of energy. It is 5.2 or 4.9, depending on whether the transition energy is taken to be 90 or 91 keV. The error in the result, due to the errors in the experimental $B(E2)$ value and the half-life, is about 10%. These estimates of the total conversion coefficient are slightly higher than 4.38, which is the value obtained by taking the theoretical values of Sliv and Band[17] for the K- and L-shell conversion coefficients and assuming the contribution of the higher shells to be 0.33 times the L-shell conversion coefficient.

E. 2006-keV State of ^{46}Ti

The measurement of the lifetime of the 2006-keV state of ^{46}Ti has been attempted in the past by some workers employing electronic methods. The mean life of this level was reported to be <30 psec by Azuma[18] and <5 psec by Lee and Wu.[19] In the present work the lifetimes of the second excited states of ^{46}Ti and ^{60}Ni are compared by means of β-γ coincidence employing ^{46}Sc and ^{60}Co sources. The sources are deposited over areas of about 1 sq mm on Mylar foils. The β and γ rays are detected by the 2.5-cm-diam$\times$3-mm-thick NE-810, and the 2.5-cm-diam$\times$5-cm-long NE-102 plastic scintillators, respectively. Measurements are done alternately with the two sources, using the same geometry in each case. For each measurement, the source is kept in contact with the β detector. The alternate sets of data are separately recorded. Figure 8 shows the coincidence data for ^{46}Ti and ^{60}Ni by points and circles, respectively. The moment analysis of the experimental data leads to a value of 10 psec, with a statistical error of about 80%, for the difference between the half-lives of the 4^+ states of ^{46}Ti and ^{60}Ni. Therefore, it is concluded that the difference between their half-lives is less than 20 psec.

F. 85-keV Level of ^{196}Au

The 85-keV level of ^{196}Au is populated in the decay of the 9.7-h ^{196m}Au. The K/L ratio for this level being very small,[20] it de-excites mostly by L-shell conversion. The possibility of a half-life of the order of a few μsec for this level was investigated as follows: The 188-keV γ ray feeding the 85-keV level and the L x rays from the 85-keV transition were detected by 5-cm$\times$5-cm, and 2-mm-thick$\times$3.75-cm-diam NaI(Tl) scintillators, respectively. The 9.7 h ^{196m}Au was produced by $(n,2n)$ reaction with 14-MeV neutrons on specpure gold taken in the form of a foil. Two sources of equal strength were produced by bombarding two identical pieces cut from the same gold foil, simultaneously with neutrons for 4 h. One of the two sources was employed for recording genuine coincidences. The random coincidences were obtained by use of the two independent sources mentioned above. Alternate runs of 30-min intervals for genuine and random coincidences were made for 8 h, with a total period of accumulation of 4 h for each. Four such 8-h runs were given in succession. In Fig. 9 the curves (a)–(d) represent the data obtained in the successive 8-h runs. In each case the continuous and dashed lines give the genuine-plus-random and random coincidences, respectively. The genuine coincidences are given by the difference of the two. The data points are

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[20] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington, 25, D.C., 1962), NRC 5-2-29.

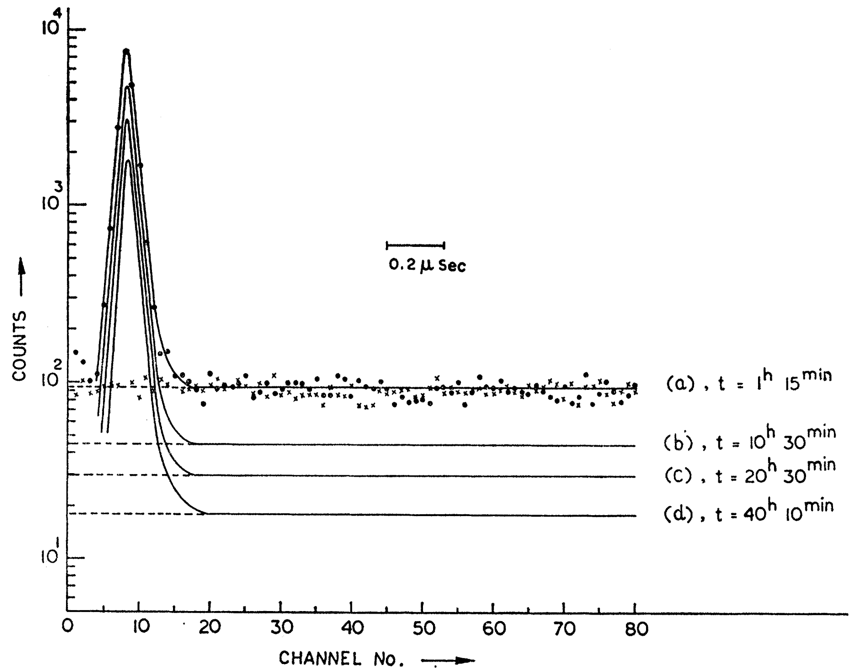

FIG. 9. Measurement of delay between the 188-keV γ ray and the L x ray emitted in the decay of the 9.7-h ^{196m}Au. Curves (a)–(d) are obtained in successive 8-h runs started at time $t = 1\frac{1}{4}$, $10\frac{1}{2}$, $20\frac{1}{2}$, and $40\frac{1}{6}$ h, after the end of the fast neutron bombardment of the gold foil.

shown only in the case of curve (a). It is seen from curve (a) that the observed coincidence counts above the random level give rise to a prompt peak with a slope of about 10 nsec but they do not give any evidence for the existence of any delay of the order of a few μsec. The intensity of the prompt peak decays in accordance with the 10-h and 6-day half-lives [curves (a)–(d), Fig. 9]. The prompt-coincidence peak is reproduced when the above experiments are repeated with the energy selection for the radiations detected by the thin NaI(Tl) scintillator changed so as to exclude the L x rays and to record the contribution of only the K x rays. Therefore, it is concluded that the half-life of the 85-keV level of ^{196}Au, reported previously to be >0.5 μsec,[20] is even greater than 4 μsec.

TABLE I. Measured half-lives of excited states of nuclei.

Nucleus	Level (keV)	Half-life (sec) Present work	Earlier measurements
$_{37}{}^{84}Rb_{47}$	250	$(3.08\pm0.55)\times10^{-10}$	...
$_{43}{}^{99}Tc_{56}$	181	$(3.40\pm0.10)\times10^{-9}$	1. $(3.5\pm0.3)\times10^{-9}$ [a] 2. $(3.575\pm0.05)\times10^{-9}$ [b] 3. $(3.59\pm0.05)\times10^{-9}$ [c] 4. (3.45 ± 0.06) 10^{-9} [d]
$_{66}{}^{162}Dy_{96}$	1148	$(2.10\pm0.40)\times10^{-10}$	...
$_{68}{}^{164}Er_{96}$	90	$(1.52\pm0.06)\times10^{-9}$	1. $(1.4\pm0.5)\times10^{-9}$ [e] 2. $(1.732\pm0.003)\times10^{-9}$ [f] 3. $(1.43\pm0.05)\times10^{-9}$ [g]
$_{22}{}^{46}Ti_{24}$	2006	$<2\times10^{-11}$	1. $<3\times10^{-11}$ [h] 2. $<5\times10^{-12}$ [i]
$_{43}{}^{99}Tc_{56}$	920	$<1\times10^{-10}$	$<1\times10^{-10}$ [j]
$_{79}{}^{196}Au_{117}$	85	$>4\times10^{-6}$	$>5\times10^{-7}$ [k]

[a] See Ref. 6.
[b] See Ref. 7.
[c] See Ref. 8.
[d] See Ref. 5.
[e] See Ref. 12.
[f] See Ref. 13.
[g] See Ref. 14.
[h] See Ref. 18.
[i] See Ref. 19.
[j] See Ref. 5.
[k] See Ref. 20.

3. SUMMARY OF EXPERIMENTAL RESULTS

The half-lives of excited states of various nuclei obtained in the present work are summarized along with the previously known values in some cases, in Table I.

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