Decay Schemes of the Isomers of Tc^{95} and Tc^{97}†

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An investigation of the decay schemes of Tc^{95} and Tc^{97} has been made by using high-resolution conversion-electron spectrographs, gamma-ray scintillation detectors, and coincidence techniques.

In addition to the 38.9-kev isomeric transition in Tc^{95}, eight transitions of the following energies have been assigned to Mo^{95}: 204.2, 583.9, 763, 767.9, 784, 788.0, 822.5, and 837.3 kev. A decay scheme is proposed.

The isomer of Tc^{97} has been shown to decay by a single $M4$ transition of 96.5±0.1 kev. The experimental $K:L:M$ relative conversion-electron intensities for this transition are 1:0.48:0.13.

INTRODUCTION

THE energy levels of Mo^{95} populated by the decay of the 60-day isomer of Tc^{95} have previously been studied by Medicus, Preiswerk, and Scherrer[1] and also by Levi, Papineau, and Saunier.[2] The work reported in this paper is based principally on the results of high-resolution conversion-electron spectroscopic studies, supplemented by gamma-ray scintillation spectroscopy and coincidence work. In addition to the transitions reported by the previous authors, several new transitions have been observed.

Cork, Brice, Schmid, and Helmer[3] have reported that the isomer of Tc^{97} decays through a 90.2-kev $E3$ transition and a 99.2-kev $M4$ transition, analogous to Tc^{99m}. The results of the work reported herein do not confirm the work of Cork *et al.*, but show that the isomer decays by a single $M4$ transition.

INSTRUMENTS AND EXPERIMENTAL PROCEDURE

High-resolution studies of long-lived accelerator-produced isotopes are very difficult because of the small amounts of activity that can be produced. In this work we have been able to make reasonably large amounts of the 60-day isomer of Tc^{95} and the 90-day isomer of Tc^{97} by bombarding natural molybdenum with the intense 7.4-Mev deuteron beam of the Livermore A-48 accelerator.[4]

Chemical processing of the target was delayed 3 months to allow the shorter-lived activities to decay. The target was dissolved in a solution of HCl and HNO_3 and evaporated nearly to dryness. The precipitate that formed was then digested in a small volume of HNO_3 so that the bulk of the molybdenum would precipitate as molybdic acid. After the solution was cooled to reduce the solubility of the molybdic acid, the supernatant liquid containing most of the technetium activity was removed. The molybdic acid precipitate was dissolved and reprecipitated three times in order to obtain the remaining technetium occluded in the precipitate. The technetium was then separated from the remaining soluble molybdenum by use of an anion-exchange separation.[5] The technetium obtained in this manner was mass-free. Most of the activity was used to prepare a source for the conversion-electron studies. This source was prepared by cathodic electrodeposition of the technetium activity onto a 0.010-inch platinum wire. The remaining activity was used to prepare sources for the gamma-ray analysis.

The gamma-ray spectra were obtained using 1×1½-inch and 3×3-inch cylindrical NaI(Tl) scintillation crystals in conjunction with a 100-channel pulse-height analyzer. The gamma-gamma-ray coincidence measurements were performed with a coincidence circuit having a resolving time of 2 microseconds. In each coincidence experiment the chance coincidence spectrum was subtracted from the observed coincidence spectrum.

The high-resolution conversion-electron studies were performed on two permanent-magnet spectrographs with magnetic fields of 99 and 350 gauss.[6] These spectrographs are very useful for studying long-lived activities, since the photographic emulsion used as a detector can integrate the line intensities over a very long period of time. For the very weakly converted high-energy transitions an exposure of one month was required.

Tc^{95} GAMMA-RAY SPECTRA

Spectrum A of Fig. 1 illustrates the singles gamma-ray spectra taken with the 1×1½-inch NaI crystal. In addition to the K x-rays, gamma rays of 204, 580, 820, and 1040 kev were observed. The 820-kev peak was the only one that appeared to be complex. All the gamma rays decayed with a half-life of 61±2 days. These gamma rays were therefore assigned to the decay of Tc^{95m}, which has been previously reported to have a half-life of about 60 days.[7] Medicus *et al.*[1] have reported gamma rays of 201, 510, 810, and 1017 kev, but did not observe that the 810-kev gamma ray was

† Work done under the auspices of the U. S. Atomic Energy Commission.

[1] Medicus, Preiswerk, and Scherrer, Helv. Phys. Acta. **23**, 299 (1950).
[2] Levi, Papineau, and Saunier, Compt. rend. **245**, 1918 (1957).
[3] Cork, Brice, Schmid, and Helmer, Phys. Rev. **100**, 188 (1955).
[4] Birdsall, Clark, Jaspon, Livdahl, Smith, and Van Atta, Bull. Am. Phys. Soc. **2**, 187 (1957).
[5] Huffman, Oswalt, and Williams, J. Inorg. Nuclear Chem. **3**, 49 (1956).
[6] W. G. Smith and J. M. Hollander, Phys. Rev. **101**, 746 (1956).
[7] For reference see Strominger, Hollander, and Seaborg, Revs. Modern Phys. **30**, 585 (1958).

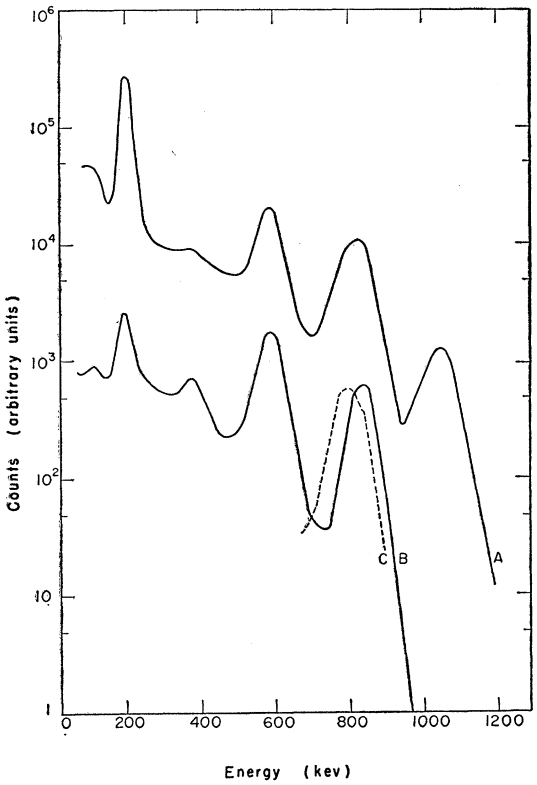

FIG. 1. Singles and coincidence gamma-ray spectra of Tc^{95m}. Curve *A*—singles spectrum. Curve *B*—gamma-ray spectrum in coincidence with 204-kev gamma ray. Curve *C*—complex photopeak not in coincidence with the 204-kev gamma ray.

complex. The *K* x-rays decayed with a half-life longer than 60 days, indicating the presence of the 90-day isomer of Tc^{97}.

Table I summarizes the gamma rays of Tc^{95m} that were observed and their corresponding relative intensities. The intensities given represent an average of the intensities obtained by using $1\times1\frac{1}{2}$-inch and 3×3-inch cylindrical NaI(Tl) scintillation crystals. The photopeak efficiency curves of Kalkstein and Hollander[8] were used for the $1\times1\frac{1}{2}$-inch crystal and the photopeak efficiency curves given by Heath[9] were used for the 3×3-inch crystal.

The relative intensity of *K* x-rays due to Tc^{95} was distinguished from the *K* x-rays of Tc^{97} by resolving the decay curve of the *K* x-rays taken over a period of one year.

TABLE I. Gamma rays of Tc^{95m}.

Energy (kev)	Relative intensity
K x-rays	1.6 ±0.4
204±2	1.8 ±0.2
580±6	1.0
820±10	1.45±0.15
1040±10	0.10±0.02

[8] M. I. Kalkstein and J. M. Hollander, University of California Radiation Laboratory Report UCRL-2764, October, 1954 (unpublished).

[9] R. L. Heath, Atomic Energy Commission Report IDO-16408, July, 1957 (unpublished).

The results of the gamma-gamma coincidence measurements can be summarized as follows:

(1) The 204-kev gamma ray is in coincidence with the high-energy side of the 820-kev complex photopeak, spectrum *B* of Fig. 1. It was found by gating on the 204-kev peak and comparing the coincidence spectrum to the singles spectrum that 53±5% of the 820-kev peak was in coincidence with the 204-kev gamma ray. This gamma ray, then, has an intensity of 0.77±0.08 relative to the 580-kev gamma ray.

(2) The energy of the gamma ray in coincidence with the 204-kev gamma ray is 840±20 kev and appears to be a single gamma ray when the peak width is compared to the 662-kev gamma ray of Cs^{137} and the 1064-kev gamma ray of Bi^{207}. After subtracting out the contribution of the 1040-kev gamma ray from the singles spectrum (using the 1064-kev gamma ray of Bi^{207} as a standard) and then subtracting the coincidence spectrum from the resultant singles spectrum, one obtains a complex peak at 800±20 kev, spectrum *C*, Fig. 1. This complex peak has a half-width about 20 kev greater than that of the 840-kev gamma ray.

(3) The 580-kev gamma ray is completely in coincidence with the 204-kev gamma ray.

(4) The 580-kev and the complex 820-kev gamma rays are not in coincidence.

(5) The 1040-kev gamma ray is not in coincidence with any gamma ray.

TABLE II. Conversion-electron lines of Tc^{95m} (99-gauss spectrograph).

Electron energy (kev)	Shell of conversion	Transition energy (kev)	Relative electron intensities
17.88±0.1	*K*[a]	38.9±0.1	
36.19±0.4	*L*[a]	38.9	
38.44±0.4	*M*[a]	38.9	
184.2 ±0.2	*K*	204.2±0.2	100
201.3 ±0.2	*L*	204.2	13±2
203.7 ±0.2	*M*	204.2	4±1

[a] Internal conversion occurs in technetium; lines not so designated occur in molybdenum.

CONVERSION-ELECTRON SPECTRA OF Tc^{95m}

Tables II and III summarize the conversion-electron work. Because of the small differences between different *L*- and *M*-subshell binding energies, the subshell of conversion for a particular transition could not be determined uniquely. The final transition energies are determined from the *K*-conversion electron lines, by use of the binding energies given by Hill, Church, and Mihelich.[10] The relative electron intensities were determined by taking a densitometer tracing of the emulsion, relating photographic densities to relative intensities by

[10] Hill, Church, and Mihelich, Rev. Sci. Instr. **23**, 523 (1952).

the method of Slätis[11] and also by visual comparison of the conversion-electron lines to standard exposed emulsions. The intensities so obtained were corrected for the different geometries and photographic blackening efficiencies. For the first three electron lines in Table II, the relative intensities were difficult to estimate, since the lines were rather diffused and in a high background.

POSITRONS

Since the 510-kev annihilation-radiation photopeak was masked by the intense 580-kev photopeak, the relative number of positrons to a particular gamma ray could not be determined directly by comparing the relative gamma-ray intensities. However, the ratio of positrons to the 580-kev gamma ray was obtained in the following manner. The 510–510 kev annihilation radiation coincidence counting rate (A) in the technetium sample was determined. According to the previous coincidence work, there will be no complication due to other gamma-ray coincidences. From energy considerations it can be shown that the 580-kev gamma ray and higher-energy gamma rays cannot be in coincidence with positrons. Levi and Papineau have determined from (p,n) thresholds that the available energy for electron capture for the isomer is 1.73 Mev.[12] Since the 580-kev gamma ray is in coincidence with the 204-kev gamma ray, and it is to be shown (later in this paper) that the first excited state is at 204 kev, the 580-kev gamma ray must depopulate a level at about 784 kev. From the $Q_{E.C.}$ the highest energy level that can be populated is 710 kev. Therefore the 580-kev gamma ray and the higher-energy gamma rays observed cannot be in coincidence with positrons. With the same geometry, the 510–510 kev coincidence rate (B) was measured for a Na^{22} sample. Both samples were surrounded by an appropriate thickness of aluminum to stop all positrons. Then the singles counting rates of both samples were determined, which gave the sum of the 510- and 580-kev gamma rays counting rate (C) in the technetium sample and the 510-kev annihilation-radiation counting rate (D) in the Na^{22} sample. The number of positrons relative to the 580-kev gamma ray is then given by

$$N(B^+)/N(580)=\tfrac{1}{2}AD/(BC-AD).$$

The ratio of positrons to the 580-kev gamma ray was found to be 0.010 ± 0.003. The number of positrons relative to the 204-kev gamma ray is then 0.0056 ± 0.0018. This ratio differs appreciably from the value of 1.1×10^{-3} relative to the 204-kev gamma ray reported by Levi, Papineau, and Saunier.[2] Using the value of 1.6 for the K x-ray intensity relative to the 580-kev gamma ray, a fluorescence yield of 0.73,[13] and a L/K capture ratio of 0.11,[14] one obtains an estimate of the positron-to-electron-capture ratio of $0.4\pm0.16\%$. This value agrees with the value of 0.4% reported by Medicus *et al.*[1]

TABLE III. High-energy conversion-electron lines of Tc^{95m} (350-gauss spectrograph).

Electron energy (kev)	Shell of conversion	Transition energy (kev)	Relative electron intensities
563.9±0.6	K	583.9±0.6	100
580.8±0.6	L	583.9	13±2
743 ±2	K	763 ±2	~1
747.9±0.8	K	767.9±0.8	5±1
764 ±2	K	784.0±2	~2
768.0±0.8	K	788.0±0.8	14±2
785 ±2	L	788.0	~2
802.5±0.8	K	822.5±0.8	6±1
817.3±0.8	K	837.3±0.8	40±4
834.5±1.6	L	837.3	4±1

ENERGY LEVELS OF Mo^{95}

The 38.9-kev transition is highly converted, and from the energy spacings of the K and L lines it is clear that the internal conversion occurs in technetium and not in molybdenum. These facts strongly suggest that this transition corresponds to an isomeric transition in technetium. The isomeric transition is probably in Tc^{95}, as was reported by Medicus and Preiswerk.[15] Medicus and Preiswerk reported the transition energy as 39.0 ± 0.7 kev, in good agreement with the energy obtained in this work, and they determined the half-life of the transition to be 60 ± 10 days.

The first excited state of Mo^{95} has been shown to be at 204 kev by several investigators,[1,16] and therefore the 204.2-kev transition is assigned as depopulating the first excited state. This is consistent with all the coincidence data and the fact that the 204.2-kev transition is the most intense in the decay.

The 204.2-kev transition was found to be in coincidence with the 580-kev gamma ray, the energy of which was more accurately determined as 583.9 kev from the conversion-electron spectroscopy. This result suggests that an energy level exists at $583.9+204.2=788.1$ kev. This postulate is substantiated by the observation in the conversion-electron spectra of a 788.0-kev transition, the crossover transition to the ground state.

The 204.2-kev transition is also in coincidence with the high-energy side of the 820-kev complex gamma-ray peak. The energy of this gamma ray in coincidence with the 204.2-kev transition was found to be 840 ± 20 kev, and it appears to be a single gamma ray. This transition is most likely the 837.3-kev transition observed in the conversion-electron work. Since the 837.3-

[11] H. Slätis, Arkiv Fysik **8**, 441 (1954).
[12] C. Levi and L. Papineau, Compt. rend. **244**, 1358 (1957).
[13] I. Bergström, in *Beta- and Gamma-Ray Spectroscopy*, edited by K. Siegbahn (Interscience Publishers, Inc., New York, 1955), p. 630.
[14] M. E. Rose and J. L. Jackson, Phys. Rev. **76**, 1540 (1949).
[15] H. A. Medicus and P. Preiswerk, Phys. Rev. **80**, 1101 (1950).
[16] F. K. McGowan and P. H. Stelson, Phys. Rev. **109**, 901 (1958).

kev transition is in coincidence with the 204.2-kev transition, there is good evidence that an energy level exists at 1042 kev. This postulated energy level is substantiated by the observation of a 1040±10-kev gamma ray, which is not in coincidence with any gamma ray.

The gamma-ray photopeak not in coincidence with the 204.2-kev transition was complex, with a width at half maximum about 20 kev greater than that of the 840-kev gamma ray. This photopeak is most likely due to the 767.9-, 788.0-, and 822.5-kev transitions.

The coincidence results confirm the postulate that the 788.0-kev transition observed in the conversion electron work is the crossover transition to the ground state.

The 767.9-kev transition is very likely the transition that has been observed in the 20-hour electron capture of the ground state of Tc^{95} (762 kev)[1] and the beta decay of Nb^{95} (767±2 kev,[17] 768±1.5 kev,[18] and 770±2 kev[19]) This transition has been shown to go directly to the ground state, in agreement with this work.

Since the 822.5-kev transition is not in coincidence with any gamma ray, it is assigned as going directly to the ground state.

Very little can be said conclusively at this time concerning the coincidence relations of the 763- and 784-kev transitions with the 204.2-kev transition, because of their relatively low intensities. If these transitions have comparable or smaller conversion coefficients relative to the other high-energy transitions, it would be unlikely that they are in coincidence with the 204.2-kev transition.

GAMMA TRANSITION MULTIPOLARITIES

The 204.2-kev transition has been shown by recent Coulomb-excitation work[16] to be an $M1$-$E2$ mixture, with a mixing ratio $E2/M1$ of 0.34±0.17. The K/L conversion electron ratio of 7.7±1.2 obtained in this work is consistent with such an $M1$-$E2$ admixture. The theoretical K/L ratio for an $M1$ transition is 8.8; for $E2$ the ratio is 7.1. The theoretical conversion coefficients of Sliv and Band[20] are used throughout this paper.

The multipolarity assignments from conversion coefficients for the other gamma rays are very difficult to make because, with the exception of the 584- and 837-kev transitions, the relative gamma-ray intensities could not be obtained. Also at this particular atomic number for the energies under consideration, the conversion coefficients for $M1$ and $E2$ multipolarities are very similar. At 584 kev the two conversion coefficients differ by about 15%, while at 837 kev they differ by only about 5%. Also the K/L ratios obtained from the emulsions in this work are considered to have an uncertainty too large to allow one to unambiguously distinguish between $M1$ and $E2$ multipolarity.

In this work the absolute conversion coefficient for the 584-kev transition was not determined. However, from the conversion-coefficient work of Medicus *et al.*[1] the 584-kev transition was shown to be either $M1$ or $E2$. The experimental ratio of the K-conversion coefficient for the 584-kev transition to that of the 837-kev transition, from this work, is 1.9±0.3. If the 584-kev transition were of $M1$ multipolarity and the 837-kev transition $M1$ or $E2$, the theoretical ratio would be 2.2. If the 584-kev transition were $E2$, the ratio would be 2.6. Therefore the 584-kev transition is more likely to be $M1$ and the 838-kev transition $M1$ or $E2$.

The 768-kev transition has been shown by Drabkin, Orlov, and Rusinov to be of $E2$ multipolarity.[19]

The 788-kev transition cannot involve a parity change, since it is the cross-over transition connecting two states of the same parity. Both the 584- and the 204.2-kev transitions have been shown to involve no parity change.

Limits on the multipolarities of the 788- and 822-kev transitions can be obtained from the relative conversion-electron intensities. The gamma-ray and conversion-electron intensities were normalized to both the 584- and the 837-kev transitions by using the theoretical $M1$ conversion coefficient and the average of the theoretical $M1$ and $E2$ conversion coefficients, respectively. The gamma-ray intensities for the transitions were then calculated from the relative conversion-electron intensities by assuming various multipolarities and using the theoretical conversion coefficients. The sum of the calculated gamma-ray intensities was then compared to the experimental sum of 0.68±0.17 for the intensity of the gamma rays, relative to the 584-kev transition, which were not in coincidence with the 204.2-kev transition. In both cases, with the 768-kev transition of $E2$ multipolarity, the data are consistent with multipolarity assignments of $M1$ or $E2$ for the 788-kev transition and $E1$, $M1$, or $E2$ for the 822-kev transition. No limits can be set on the multipolarities of the 763- and 784-kev transitions because of their low intensities.

ENERGY-LEVEL SCHEME OF Mo^{95}

Figure 2 represents the energy-level scheme, with spin assignments and transition intensities in terms of percent of total decay included. The relative intensities for the 768-, 788-, and 822-kev transitions were obtained from the relative conversion-electron intensities by normalizing the data to the conversion-electron and gamma-ray intensities of the 584-kev transition by using the theoretical $M1$ conversion coefficient. The intensity of the 822-kev transition was determined by assuming $M1$ or $E2$ multipolarity. The justification of this assignment in preference to $E1$ is given later in this section. The approximate maximum limits on the intensities of the 763- and 784-kev transitions were deter-

[17] K. E. Johansson, Arkiv Fysik **10**, 247 (1956).
[18] Cork, LeBlanc, Martin, Nester, and Brice, Phys. Rev. **90**, 579 (1953).
[19] Drabkin, Orlov, and Rusinov, Izvest. Akad. Nauk S.S.S.R. Ser. Fiz. **19**, 324 (1955); Columbia Tech. Translation p. 294.
[20] Tables by L. A. Sliv and I. M. Band, Leningrad Physico-Technical Institute Reports [translation: Report 57ICCK1, 1956, and Report 58ICCL1, 1958, issued by Physics Department, University of Illinois, Urbana, Illinois (unpublished)].

mined by assuming the maximum photon intensity, that is, the intensity if both the transitions were $E1$.

From the observed intensities of the transitions populating the first excited state and the intensity of the 204.2-kev transition, an upper limit of the electron capture to the first excited state can be set as 10%, and the data are consistent with no capture to this state. Because of the larger uncertainty of the K x-ray intensity, we can only set the less restrictive upper limit of the electron capture to the ground state as 20%. These limits are consistent with those of Levi *et al.*[2] who have reported less than 10% electron capture to the ground state and less than 10% to the first excited state.

Table IV lists the experimental logft values for electron capture to the various energy levels. Levi *et al.*[2] have reported observing approximately equally intense positron groups of 680±30 and 460±30 kev populating the ground state and the first excited state of Mo^{95}, respectively. Assuming equally intense positron groups, we calculate the logft values for positron emission of 9.0 and 8.2 for the ground state and the 204.2-kev level, respectively.

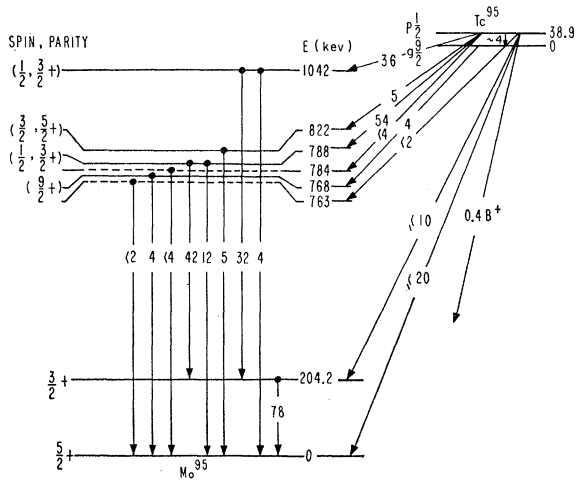

FIG. 2. Decay scheme of Tc^{95m}. Transition intensities are given as percent of total decay.

The ground state of Mo^{95} has a measured spin of $\frac{5}{2}$,[21,22] in agreement with the shell-model prediction of $\frac{5}{2}+$ due to a $(d_{\frac{5}{2}})^3$ neutron configuration.

The 204.2-kev transition is primarily of $M1$ multipolarity, which indicates that the first excited state could have a spin of $\frac{3}{2}+$, $\frac{5}{2}+$, or $\frac{7}{2}+$. However, from angular distribution and polarization-direction correlation, McGowan and Stelson[16] have shown that the spin of the first excited state must be $\frac{3}{2}+$.

From this work alone little can be said conclusively regarding the spin and parity of the energy level at 768 kev, but from other work on the decay of the ground state of Nb^{95} the spin has been shown to be $9/2+$.[19] In this work, this energy level is probably not populated directly from the decay of the $\frac{1}{2}-$ isomeric state of Tc^{95} but rather from the decay of the $9/2+$ ground state of Tc^{95}, which is in turn populated by the isomeric transition. Medicus *et al.*[1] have reported that 90% of the ground-state decay of Tc^{95} goes to the 768-kev level. Using this percentage, taking the intensity of the 768-kev transition from this work, as calculated by using the theoretical $E2$ conversion coefficient, and assuming no population from the isomeric state, we calculate that ~4% of the decay of Tc^{95m} proceeds through the isomeric transition. The value reported by Medicus *et al.* is 3%. Therefore very little, if any, direct population of this state comes from the $\frac{1}{2}-$ isomeric state of Tc^{95}, as would be expected.

TABLE IV. Experimental logft values for electron capture.

Energy level	Logft
0	≥7.98
204	≥8.17
763	≥8.5
784	≥8.1
788	7.02
822	7.98
1042	6.92

The energy levels at 788 and 1042 kev decay primarily to the $\frac{3}{2}+$ first excited state with an appreciable branching to the $\frac{5}{2}+$ ground state. It should be noted that the logft values and the modes of de-excitation are very similar for these two states. For both these states, spin values of $\frac{1}{2}+$ or $\frac{3}{2}+$ would be consistent with the modes of depopulation, the assignment of $M1$ multipolarity for the 584-kev transition, $M1$ or $E2$ multipolarity for the 788- and 837-kev transitions, and the logft values for these states.

The 822-kev transition has been shown to be of either $E1$, $M1$, or $E2$ multipolarity. The occurrence of an odd-parity state at an energy such as this and in this region just three neutrons from a closed shell is unlikely. The logft value of 7.6 calculated by assuming that the 822-kev transition is of $E1$ multipolarity is inconsistent with most logft values for allowed or second-forbidden transitions. However, the logft value of 7.98 calculated by assuming $M1$ or $E2$ multipolarity is consistent with an assignment of $\Delta I=\pm 1$ or 2, yes, for the electron capture to this state. On this basis, the energy level at 822 kev is assigned tentatively as $\frac{3}{2}+$ or $\frac{5}{2}+$.

The 763- and 784-kev transitions have been tentatively assigned as going directly to the ground state. This assignment is not completely certain due to the low intensity of these transitions. Again, on the assumption that these transitions are both of $E1$ multipolarity, the calculated logft values of ~8.5 and ~8.2 for the 763- and 784-kev transitions, respectively, are not consistent with allowed or second-forbidden transitions. On the other hand, the logft values of ~8.9 and ~8.6, respectively (assuming $M1$ or $E2$ multipolarity), are consistent with $\Delta I=\pm 2$, yes. It should be pointed out

[21] E. C. Woodward, Phys. Rev. **93**, 954 (1954).
[22] J. Owen and I. M. Ward, Phys. Rev. **102**, 591 (1956).

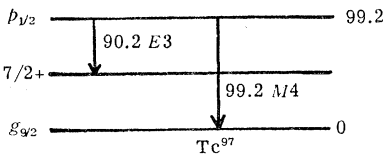

FIG. 3. Decay scheme of Tc^{97m} as reported by Cork *et al.* Energies in kev.

at this time that we have not ruled out the possibility that these transitions are populated in the decay of the ground state of Tc^{95}. Medicus *et al.*,[1] in their work, probably could not resolve the transitions of 763 and 768 kev.

DISCUSSION

The decay of the isomeric state and the ground state of Tc^{95} are very interesting, since in each case a different set of energy levels of Mo^{95} is populated owing to the large difference in the spins of the two initial states. In this work it is shown that the decay from the isomeric state is rather complex, but according to the work of Medicus *et al.*,[1] the decay of the ground state is rather simple. Most of the electron capture from the ground state goes to the energy level at 768 kev, and there is a small branching to levels at 930 and 1070 kev. In the decay of the ground state of Nb^{95} only the level at 768 kev in Mo^{95} has been observed to be populated.

The $\frac{3}{2}+$ first excited state of Mo^{95} at 204.2 kev is rather difficult to interpret as a state with a single unpaired neutron. The logft value of $\geqslant 8.2$ for electron capture of the $p_{\frac{1}{2}}$ isomeric state of Tc^{95} to this level is rather high for a simple first-forbidden transition. Also, this excited state has a measured half-life of 7.7×10^{-10} sec.[23,24] From Moszkowski's single-particle estimates[25] the half-life of this transition would be about 2.3×10^{-12} sec if it were due to a single-neutron transition; that is, this transition is retarded by a factor of $\sim$330.

The energy difference of 204.2 kev between the $[(d_{\frac{5}{2}})^3]_{\frac{5}{2}+}$ ground state and the $\frac{3}{2}+$ first excited state is much smaller than the normal $d_{\frac{3}{2}}-d_{\frac{5}{2}}$ splitting and therefore the first excited state cannot be due to a neutron configuration such as $[(d_{\frac{5}{2}})^2(d_{\frac{3}{2}})^1]_{\frac{3}{2}+}$.

The abnormally high logft value and the long lifetime of this state may be understood if the state is due to three unpaired neutrons coupled in the configuration $[(d_{\frac{5}{2}})^3]_{\frac{3}{2}+}$. This type of coupling of three $d_{\frac{5}{2}}$ particles to yield a resultant spin of $\frac{3}{2}$ has been observed previously for the ground states of Na^{23} and Ne^{21}. Kurath[26] and Talmi[27] have shown theoretically by using interaction potentials intermediate to the "long-range" and δ-type interaction that the $[(d_{\frac{5}{2}})^3]_{\frac{5}{2}+}$ configuration in this region is of lower energy than the $[(d_{\frac{5}{2}})^3]_{\frac{3}{2}+}$ configuration. If the first excited state of Mo^{95} were actually due to a coupling of three $d_{\frac{5}{2}}$ neutrons to yield a resultant spin of $\frac{3}{2}+$, one might expect retardation of both the electron capture to this state and the 204.2-kev gamma transition depopulating this state, since both these transitions would no longer be simple single-particle transitions.

DECAY OF THE ISOMER OF Tc^{97}

Cork, Brice, Schmid, and Helmer[3] have reported the decay scheme for the 90-day isomer of Tc^{97} shown in Fig. 3 from a study of the electron capture of Ru^{97}. These assignments were based on the observation of two highly converted transitions in a conversion-electron spectrum. The K-conversion electron intensities of these two transitions were reported to be about equal. No half-life determination was made by Cork *et al.* on these conversion lines.

TABLE V. Comparison of gamma-decay transition probabilities.

	λ sec^{-1}
Experimental	2.9×10^{-10}
Moszkowski[a]	5.1×10^{-9}
Goldhaber and Sunyar[b]	3.4×10^{-10}

[a] See reference 25.
[b] See reference 28.

In this study the K, L, and M conversion-electron lines of a very highly converted transition in technetium of 96.5 ± 0.1 kev were observed. No other conversion-electron lines were observed in this energy region. To assign this transition to Tc^{97m}, the half-life of the conversion-electron lines was determined over a period of one year. The half-life observed was 87 ± 3 days, in good agreement with the reported half-life of Tc^{97m} of about 90 days.[7]

The experimental $K:L:M$ relative conversion-electron intensities are $1:(0.48\pm0.05):(0.13\pm0.02)$. The K/L ratio of 2.1 ± 0.2 agrees very well with the theoretical ratio of 2.0 for an $M4$ transition.

The gamma-decay transition probability was also calculated by using the theoretical K-conversion coefficient, the theoretical K/L ratio, the experimental K/M ratio, and the experimental half-life of 87 ± 3 days. This decay constant is compared to the value calculated from the estimates of Moszkowski[25] using the appropriate statistical factor, and also to the empirical equation of Goldhaber and Sunyar[28] in Table V.

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