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Levels in ^{133}I from the Decay of ^{133m}Te and ^{133g}Te†

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The level structure of ^{133}I excited in the β decay of 54-min ^{133m}Te and 12-min ^{133g}Te has been studied using Ge(Li) γ-ray spectrometers in conjunction with a 4096-channel pulse-height analyzer. Coincidence measurements were carried out using two NaI(Tl) spectrometers and a 256×256-channel coincidence analyzer. Sources of ^{133g}Te were made, free of ^{133m}Te, by an isomeric separation method. All 14 transitions associated with the decay of ^{133g}Te have been placed in a consistent decay scheme on the basis of the coincidence measurements, relative intensities, and energy combinations. Levels in ^{133}I populated from ^{133g}Te occur at 311.99, 719.65, 786.77, 1312.8, 1333.23, 1564.1, 1717.65, and 2193.5 keV. From a β endpoint measurement using an anthracene detector, a total disintegration energy for ^{133g}Te of 2.96 MeV was obtained. Log*ft* values and β branching ratios have been calculated from the γ-ray intensities. The decay scheme of ^{133m}Te is quite complex, with 63 additional γ rays having been identified with this activity. Of these, only three have been unambiguously placed in the decay scheme. They require the existence of additional levels in ^{133}I at 912.58, 1560.0, and 1776.5 keV.

INTRODUCTION

The isomeric pair, ^{133m}Te-^{133g}Te, is produced in fission of ^{235}U both directly and as products of the decay of ^{133}Sb. These activities have been observed previously and half-lives of 54 and 12.4 min, respectively, have been assigned to them.[1] Previous studies of the decay of ^{133m}Te and ^{133g}Te include NaI(Tl) scintillation measurements of an equilibrium mixture of these isotopes by Ferguson, Love, and Sam[2] and of ^{133g}Te by Prussin and Meinke.[1] A total of eleven γ rays were assigned to the equilibrium mixture whereas five were identified in the decay of the ground state. Alväger and Oelsner[3] observed that the isomeric transition accounts for 13% of ^{133m}Te decays and has an energy of 334.0 keV.

This paper reports the results of high-resolution Ge(Li) spectrometry and NaI(Tl) coincidence measurements on these isotopes. In addition the results of a β endpoint measurement for the decay of the ground-state isomer is given.

EXPERIMENTAL MEASUREMENTS

Source Preparation

Each source of Te used in this study was prepared from irradiation of 1 mg of ^{235}U, as $UO_2(NO_3)_2\cdot 6H_2O$, for 30 sec in a thermal neutron flux of 10^{13} cm^{-2} sec^{-1}. Two types of sources were prepared. Relatively pure, though not intense, ^{133g}Te sources were made using a modification of a procedure described by Prussin and Meinke.[1] This procedure is based on the known[4,5] reduction of Te^{VI} to Te^{IV} during the isomeric transition. The only interfering activity, ^{131g}Te, was reduced to a negligible amount by performing a Te separation from Sb precursors within ~4 min after fission. High-intensity, mixed sources of ^{133m}Te-^{133g}Te were made using a SbH_3 distillation procedure described by Greendale and Love.[6] These mixed sources unavoidably contained ^{131g}Te and ^{132}Te. The ^{134}Te observed in these mixed sources probably resulted from the partial distillation of fission-product Te with the SbH_3.

Because of the importance of source preparation in this work, a detailed outline of the procedures is given in the Appendix.

γ-Ray Measurements

In Figs. 1 and 2 are shown γ-ray spectra of isomerically purified 12-min ^{133g}Te taken with a 3×3-in.

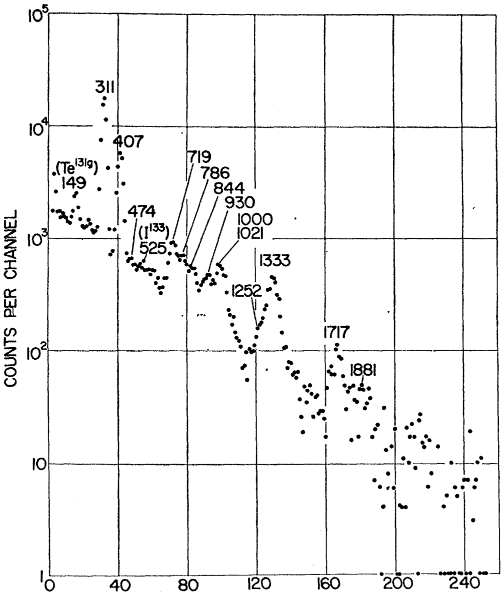

FIG. 1. γ-ray spectrum of ^{133g}Te as observed with a 3×3-in. NaI(Tl) detector at 10 cm from the source. A 1.18-gm/cm^2 beryllium β absorber was used. Energies are in kev.

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

[1] S. G. Prussin and W. W. Meinke, Radiochim. Acta 4, 79 (1965).

[2] J. M. Ferguson, D. L. Love, and D. Sam, J. Inorg. Nucl. Chem. 24, 1 (1962).

[3] T. Alväger and G. Oelsner, Arkiv Fysik 12, 319 (1957).

[4] R. R. Williams, Jr., J. Chem. Phys. 16, 513 (1948).

[5] R. L. Hahn, J. Chem. Phys. 39, 3482 (1963).

[6] A. E. Greendale and D. L. Love, Anal. Chem. 35, 632 (1963).

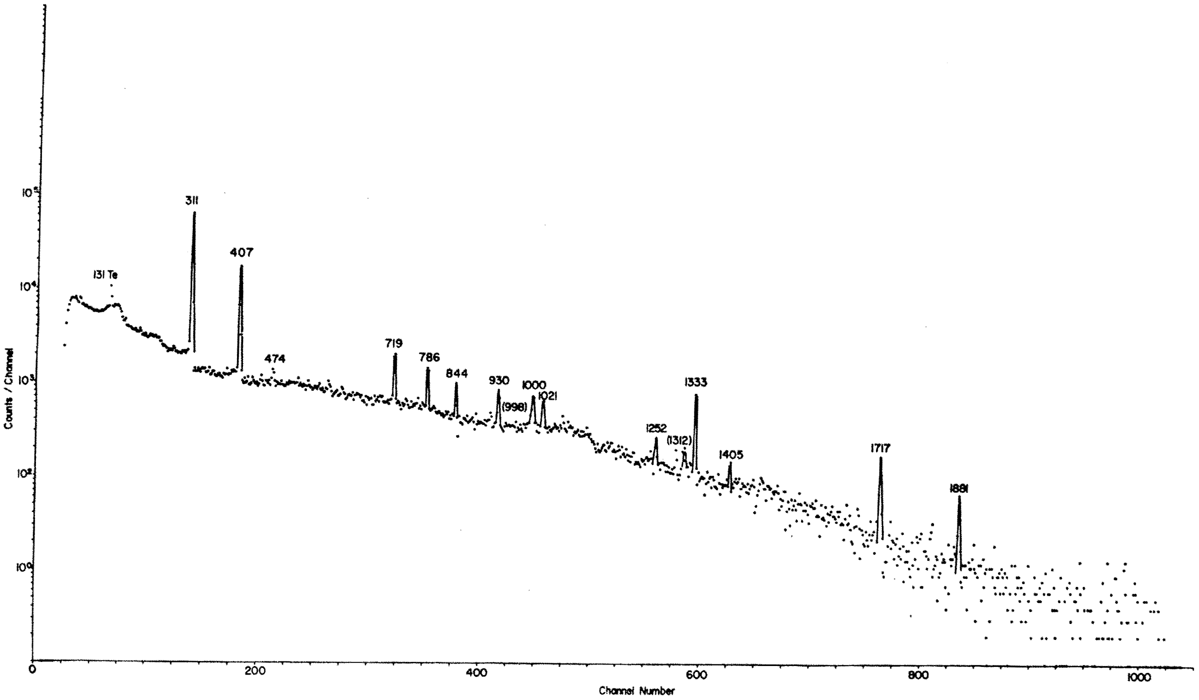

FIG. 2. γ-ray spectrum of isomerically separated ^{133g}Te as observed with a 10-cm^3 coaxial Ge(Li) detector. Energies are in keV. Background has not been subtracted.

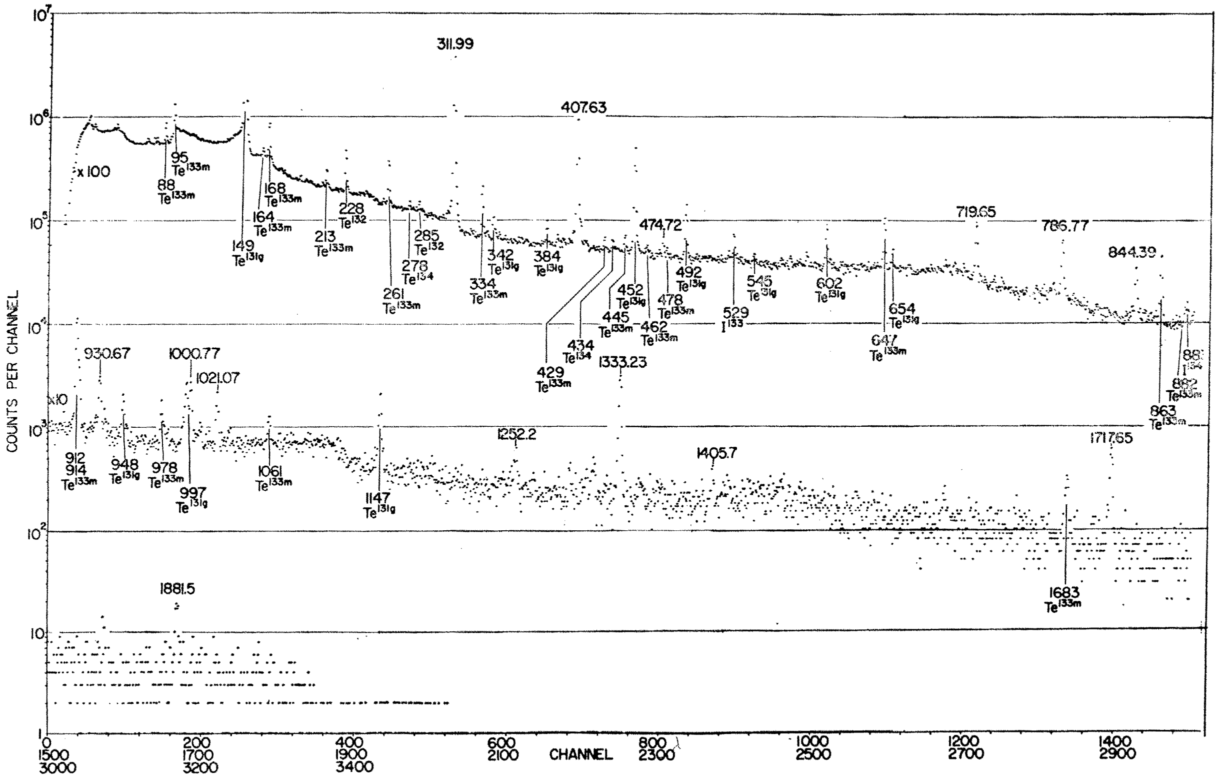

FIG. 3. γ-ray spectrum of freshly separated ^{133g}Te-^{133m}Te source as observed with a 2.5-cm^2×8-mm Ge(Li) detector. Energies are in keV. The full width at half-maximum is about 0.75 keV for a peak at 100 keV. Data-collection time was 20 min. Peaks labeled above each section are assigned to ^{133g}Te.

NaI(Tl) detector and a 10-cm^3 coaxial Ge(Li) detector, respectively. Four sources, with data-collection periods of 20 min each, were used to obtain the Ge(Li) spectrum. The Ge(Li) spectrometer had a resolution, full width at half-maximum (FWHM), of 2.8 keV at 100 keV. The use of a large-volume detector was dictated by the low source intensities. Energy and intensity measurements and half-life verification of ^{133g}Te transitions were made with mixed sources of ^{133m}Te-^{133g}Te.

γ-ray spectra of the more intense sources of ^{133m}Te-^{133g}Te were measured with a 2.5 cm^2×8 mm Ge(Li) detector with a resolution (FWHM) of 0.75 keV at 100 keV and 1.7 keV at 1 MeV. A singles spectrum of a freshly prepared source in which ^{133g}Te predominates is shown in Fig. 3. Data were collected for 20 min. The source intensity was maintained relatively constant by adjusting the source-to-crystal distance. Energy calibration of the 4096-channel spectrometer system was made using sources of ^{141}Ce, ^{51}Cr, ^{137}Cs, and ^{88}Y run concurrently with the Te source. Energy values used for these sources were, respectively, 145.44, 320.07, 661.60, 898.01, and 1836.08 keV.[7] Channel positions were determined by a method of Gaussian peak fitting and were corrected for the nonlinearity of the analyzer. These techniques are capable of establishing the position of the strong γ-ray peaks with uncertainties less than 0.1 channels.[8] Since the calibration energies are all accurate to about ±0.04 keV,[7] the strong γ rays have uncertainties of about 0.07 keV. Energies of the weak transitions were found using the previously calibrated, strong γ rays in the Te source as secondary standards. Relative intensities were determined from the area under the photopeaks and the measured efficiency of the detector. Energies and relative intensities for the transitions in ^{133g}Te, as determined from the calibration run and the spectrum shown in Fig. 3, are given in Table I.

TABLE I. Transition energies and relative intensities for ^{133g}Te. The quoted uncertainties are estimated standard deviations. The uncertainties in the intensities are less than 15%.

E_γ (keV) This study	I_γ
311.99±0.08	100
407.63±0.07	45
474.72±0.13	1.5
719.65±0.10	12
786.77±0.10	9.7
844.39±0.07	6.2
930.67±0.10	7.7
1000.77±0.11	6.4
1021.07±0.15	5.0
1252.2 ±0.2	2.0
1333.23±0.12	16
1405.7 ±0.2	1.3
1717.65±0.15	4.6
1881.5 ±0.4	2.0

TABLE II. Transition energies and relative intensities for ^{133m}Te. Those transitions following the decay of ^{133g}Te have been omitted. The uncertainties are as in Table I.

E_γ (keV)	I_γ	E_γ (keV)	I_γ	E_γ (keV)	I_γ
74.1 ±0.2	0.8	355.57±0.14	0.6	882.83±0.12	4.8
81.5 ±0.2	0.8	362.81±0.15	1.1	897.7 ±0.4	0.5
88.0 ±0.2	3.0	376.83±0.14	0.6	912.58±0.10	100
94.9 ±0.2	6.0	396.96±0.09	1.7	914.72±0.13	19
164.34±0.09	1.6	429.02±0.11	3.6	934.4 ±0.3	1.5
168.87±0.09	12	444.90±0.09	4.4	978.19±0.09	9.3
177.1 ±0.2	1.5	462.11±0.16	3.4	980.4 ±0.2	2.7
178.2 ±0.2	1.0	471.85±0.09	2.3	982.9 ±0.2	1.3
184.45±0.10	0.4	478.59±0.10	1.8	1029.8 ±0.2	1.8
193.22±0.10	1.2	519.6 ±0.2	0.5	1061.83±0.11	3.1
198.2 ±0.2	0.6	534.85±0.11	2.0	1348.9 ±0.2	2.9
213.36±0.08	4.2	574.04±0.10	3.6	1459.1 ±0.2	2.5
220.94±0.13	0.5	622.03±0.16	1.6	1516.1 ±0.3	1.1
224.03±0.13	0.4	647.40±0.08	34	1531.6 ±0.4	1.0
244.28±0.10	0.7	702.75±0.12	4.3	1587.4 ±0.2	2.2
251.49±0.10	0.6	731.69±0.15	1.7	1683.3 ±0.2	6.7
257.64±0.09	1.0	733.89±0.10	3.3	1704.4 ±0.3	1.1
261.55±0.07	14	779.75±0.10	3.9	1885.7 ±0.3	1.3
(*IT*)334.14±0.07	15	795.7 ±0.4	1.5	2004.9 ±0.3	5.4
344.5 ±0.2	1.5	800.51±0.12	2.2	2027.7 ±0.4	1.4
347.22±0.09	1.3	863.91±0.13	29	2049.2 ±0.4	1.7

To determine transition energies and relative intensities in the decay of 54-min ^{133m}Te, similar measurements were made on the mixed ^{133m}Te-^{133g}Te sources which had been allowed to decay for 1 h. Most transitions were assigned to ^{133m}Te by observing their decay in successive spectra. Weak transitions, where half-life determinations were impractical, were assigned on the basis of a combination of: (1) definitive radiochemistry, and (2) spectra taken separately of contaminating constituents (^{131g}Te, ^{132}Te, ^{134}Te, and daughters). Energies and intensities as determined from the calibration run and the spectrum shown in Fig. 4 are listed in Table II.

A series of spectra was measured in order to determine whether the levels populated in the decay of ^{133g}Te were populated directly from ^{133m}Te. These spectra were measured with a ^{133g}Te-^{133m}Te source from 10–30 min after fission, 1–2½ h, and 2–3½ hours after fission. The relative intensities of the γ rays of interest are presented in Table III. The source which decayed for 2 h before

TABLE III. Comparative intensities for major γ rays in ^{133g}Te observed in spectra taken of ^{133m}Te-^{133g}Te sources after different decay periods.

E_γ (keV)	I_γ 10 min[a]	1 h[b]	2 h[b]
311.99	100	100	100
407.63	45	43	40
719.65	12	13	10
786.77	9.7	9	···
930.67	7.7	6.8	···
1000.77	6.4	6.0	···
1021.07	5.0	6.0	···
1333.23	16	16	17
1717.65	4.6	5.0	···
1881.5	2.0	2.2	···

[a] Data collected for 20 min per source immediately after final Te separation.

[b] Data collected for 1.5 h per source after decay period.

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[7] R. G. Helmer (private communication).

[8] W. W. Black, Nuclear Technology Branches Quarterly Report, U. S. Atomic Energy Commission Report No. IDO-17140, 43, 1966 (unpublished).

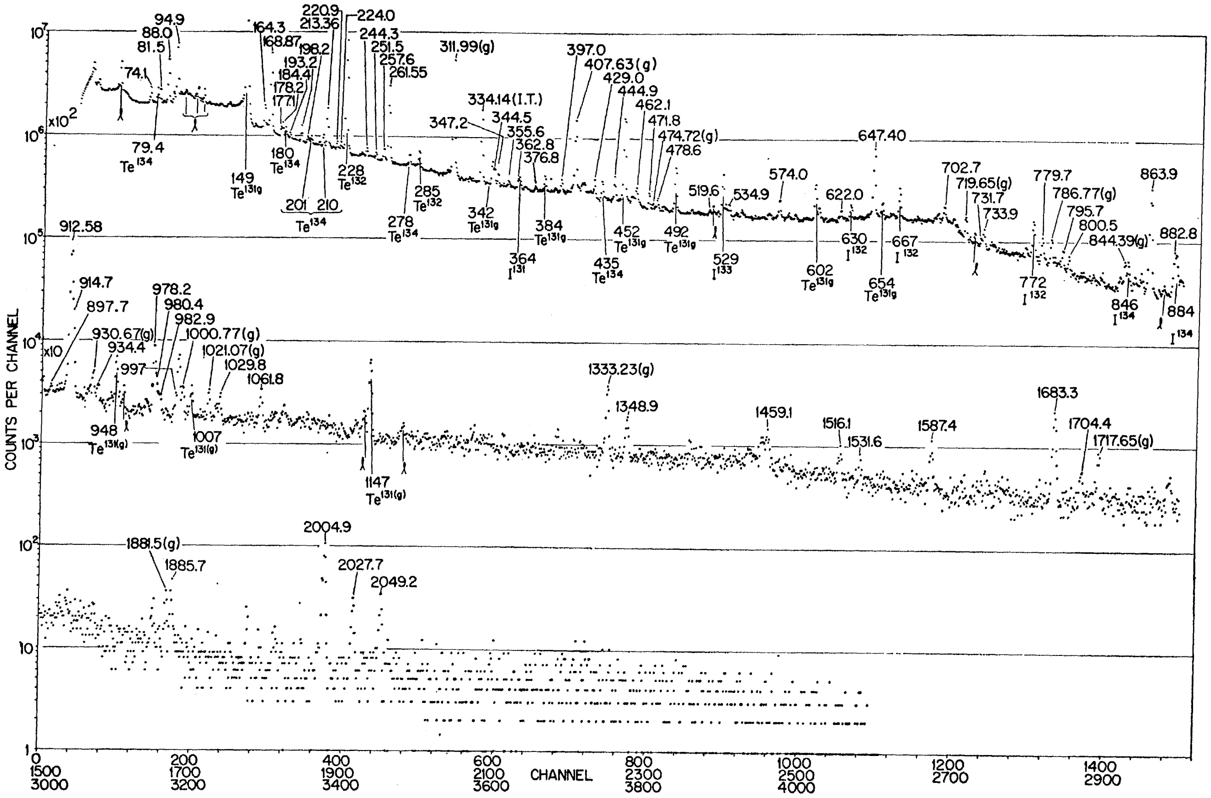

FIG. 4. γ-ray spectrum of 1-h-old ^{133g}Te-^{133m}Te source as observed with a 2.5-cm^2×8-mm Ge(Li) detector. Data-collection time was 90 min. Peaks labeled above each section are assigned to either ^{133m}Te or ^{133g}Te [indicated by (*g*)]. Some transitions from long-lived ^{131}I and ^{132}Te are labeled *l*.

analysis represents an equilibrium mixture of the isomers. These data show that these transitions are fed in significant amounts only via β decay of ^{133g}Te.

Coincidence Measurements

γ-γ coincidence measurements were carried out with two 3×3-in. NaI(Tl) detectors. The detectors were mounted with their axes at 90° and with a lead shield between them to prevent crystal-to-crystal scattering. The coincidence circuit used had a resolving time 2τ of 0.1 μsec. The timing of the circuitry was carefully set to ensure uniform coincidence efficiency throughout the energy regions of interest. Coincidence events were stored on a magnetic tape which provided 256×256 channels. For the purpose of analysis, particularly to improve counting statistics, various numbers of spectra with adjacent "gates" were added together. The coincidence data were interpreted both by visual analysis and by computer fits to selected spectra.[9]

Because of their low intensity, the isomerically purified ^{133g}Te sources were not used for coincidence measurements. For the study of the decay of ^{133g}Te, freshly prepared ^{133m}Te-^{133g}Te mixtures were used for a maximum of 15 min each. In these samples ^{133g}Te

TABLE IV. Summary of the γ-γ coincidences in the decay of ^{133g}Te. The observed coincidences are denoted by an X and those which do not exist by an O. A blank indicates the lack of definitive information.

Gate energy (keV)	311	407	474	719	786	844	930	1021 1000	1333	1717	1881	1252	1405
311		X		O	O	X	O	X	O	O	X	X	X
407	X			O	O	X	O	O	O	O	O	O	O
719						X							
786							X						
844	X	X		X									
930					X								
1000	X												
1021	X												

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[9] R. G. Helmer, R. L. Heath, L. A. Schmittroth, G. A. Jayne, and L. M. Wagner, Nucl. Instr. Methods **47**, 305 (1967).

dominated. For ^{133m}Te coincidence measurements, sources which had decayed for 1 h were used. Data were collected for 90 min per source. Total running times were 1 and 4 h for the ^{133g}Te and ^{133m}Te coincidence runs, respectively.

Samples of resulting spectra for ^{133g}Te are shown in Figs. 5 and 6, where the intense 311- and 407-keV transitions were used as gates. From coincidence results and relative intensities, it was established that the 311- and 407-keV transitions depopulate the first and second excited states, respectively. From the spectra in Figs. 5 and 6 one can determine which transitions go to these two states and the ground state. These coincidence data imply levels at 719, 1312, 1333, 1564, 1717, and 2193 keV. Coincidence relationships deduced from these and other measurements are shown in Table IV.

Results of coincidence measurements on ^{133m}Te are given in Table V. The relationship between the three strongest transitions (912, 647, and 863) is typified by the spectrum shown in Fig. 7. The spectrum obtained with the 863-keV gate is similar. As an example of the quality of the data obtained when gating with a less intense transition, the spectrum in coincidence with the 168-keV gate is presented in Fig. 8.

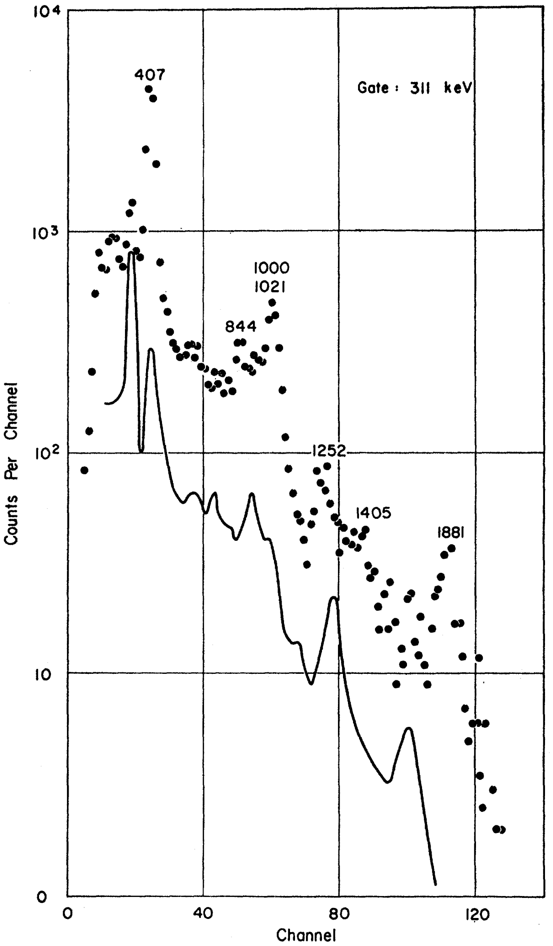

FIG. 5. γ-γ coincidence spectrum obtained with two NaI(Tl) detectors for freshly prepared ^{133g}Te-^{133m}Te sources. The gating channel was on the 311-keV peak. Total running time per source was 15 min. The solid curve represents the estimated random coincidences.

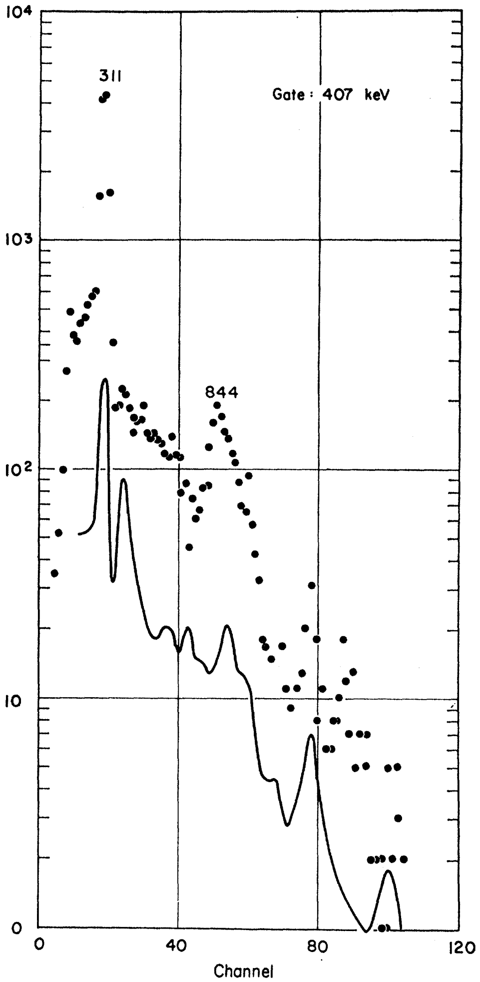

FIG. 6. γ-γ coincidence spectrum obtained with two NaI(Tl) detectors for freshly prepared ^{133g}Te-^{133m}Te sources. The gating channel was on the 407-keV peak. Total running time was 15 min per source. The solid curve represents the estimated random coincidences.

β Endpoint Measurement

A 3.8-cm-diam×1.3-cm-thick anthracene crystal was used to measure the endpoint energy of the β spectrum of an isomerically purified ^{133g}Te source. The carrier-free source was mounted on 0.7-mg/cm^2 Mylar film. Data were collected for 20 min. The spectrometer was calibrated before and after the run using the conversion electrons of ^{137}Cs and ^{207}Bi and the β rays of ^{76}As. The Fermi plots of the ^{133g}Te and ^{76}As data are shown in Fig. 9. (No correction has been made for the unique first-forbidden shape of the first component in the ^{76}As

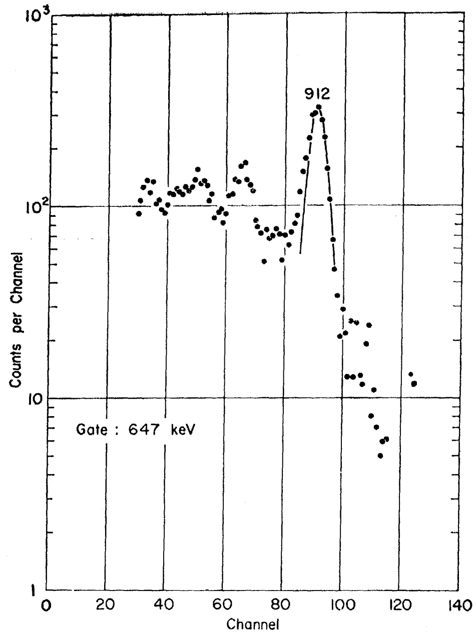

FIG. 7. γ-γ coincidence spectrum obtained with two NaI(Tl) detectors for 1-h-old ^{133g}Te-^{133m}Te sources. The gating channel was on the 647-keV peak. Total running time was 90 min per source.

spectrum.) From the measured endpoint energy (2.65 ±0.10 MeV) for ^{133g}Te a total disintegration energy of 2.96 MeV is obtained, in good agreement with the value of ~3.05 MeV expected from β-decay systematics.[10]

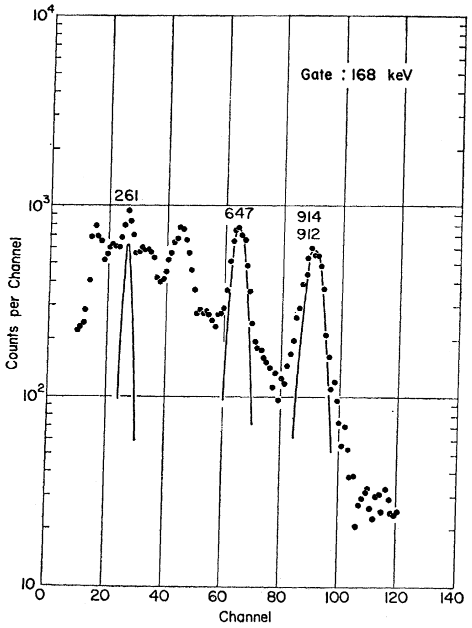

FIG. 8. γ-γ coincidence spectrum obtained with two NaI(Tl) detectors for 1-h-old ^{133g}Te-^{133m}Te sources. The gating channel was on the 168-keV peak. Total running time was 90 min per source.

Analysis of the Fermi plot gives a value of 2.25±0.20 MeV for the energy of the second β group. The energy difference of 0.4±0.1 MeV agrees with the placing of these transitions in the proposed decay scheme.

β-γ Anticoincidence

A 4π β-γ anticoincidence run was made on a carrier-free ^{133m}Te-^{133g}Te source mounted on thin plastic film. For this measurement, a 3×3-in. NaI(Tl) detector was mounted directly over a 4π β detector. The resultant anticoincident γ-ray spectrum indicated the 334-keV transition is not in coincidence with β rays and is, therefore, presumed to be the isomeric transition, in agreement with the results of Alväger and Oelsner.[3]

TABLE V. Summary of γ-γ coincidences for ^{133m}Te. See Table IV for explanation.

Gate energy (keV)	88 94	164 168	213	251 257 261	344 347	429 444	647	731 733	779 795 800	863	912 914	978 980
81 88							O			O	X	
94			X	X		X	O			O		
164 168	O			X			X			O	X	
213	X	X		X		X						
251 257 261	X	X		X			X					X
647		X								O	X	
863							O				X	
912 914		X		X	X	X	X			X	O	

DISCUSSION

Decay Scheme

^{133g}Te

On the basis of coincidence data and relative intensity and energy measurements summarized in Tables I and IV, respectively, the decay scheme shown in Fig. 10 is proposed. The 474-keV transition has been placed on the basis of energy considerations alone. The 998- and 1312-keV transitions, shown in brackets in Fig. 2, are not included in the decay scheme because of insufficient evidence as to their positions. It is tempting to suggest that they represent the 1717-to-719 and the 1312-to-ground transitions. With these exceptions, all the γ rays observed have been placed uniquely in the scheme.

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[10] *Nuclear Data Sheets*, compiled by K. Way *et al.* (U. S. Government Printing Office, National Academy of Sciences–National Research Council, Washington, D. C.), NRC-61-3-142.

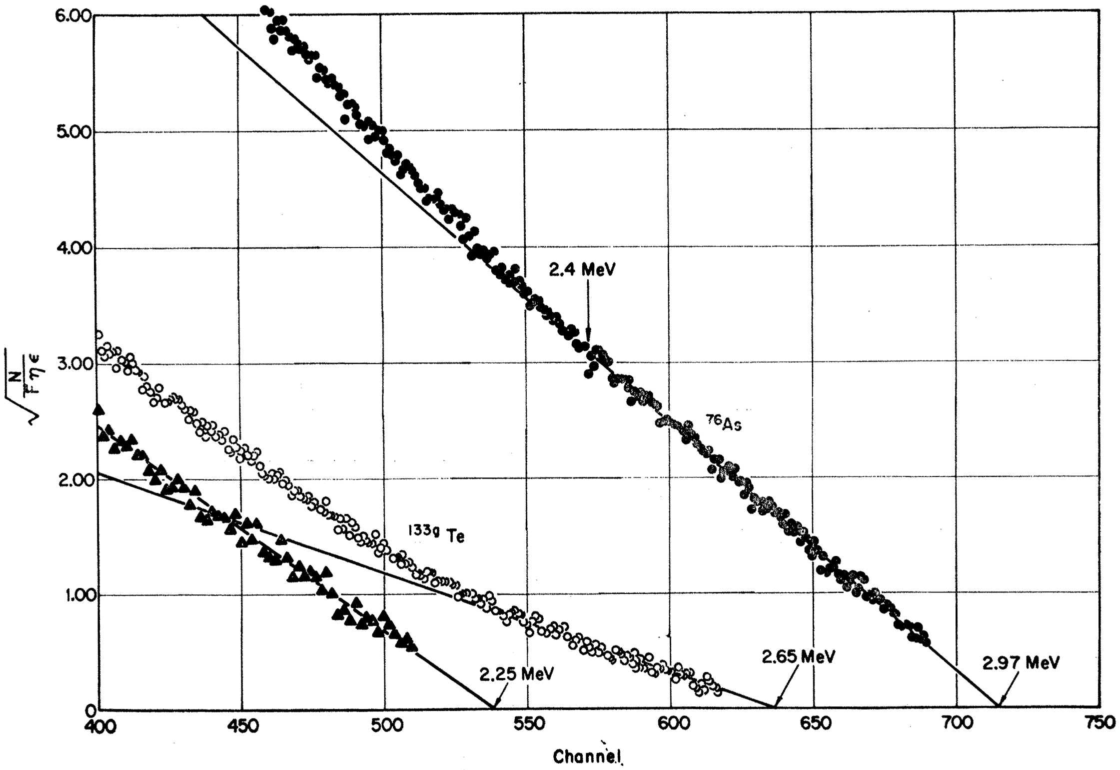

FIG. 9. Fermi plot of the ^{133g}Te β spectrum from an isomerically purified source (open circles) taken with a 3.8-cm-diam × 1.3-cm-thick anthracene crystal. The second ^{133g}Te β component (triangles) was obtained by the conventional Fermi-plot subtraction. The Fermi plot of an ^{76}As β spectrum (closed circles) taken with the same detector at the same gain is also shown. The approximate position of the second ^{76}As β component at 2.4 MeV is indicated. No correction has been made for the $(\Delta I, \Delta\pi = 2, \text{yes})$ shape of the first component in the ^{76}As spectrum.

β-ray intensities were computed from the γ-ray intensities and the decay scheme. Since any β transition to the ^{133}I ground state would be second-forbidden (see below), and hence extremely weak, it is assumed that there is no ground-state β transition and that the observed 2.65-MeV β branch populates the 311-keV first excited state.

^{133m}*Te*

Many coincidence relationships have been observed in this nuclide. Of those transitions in coincidence with the 912-914 peak, only two can be interpreted uniquely. From the γ-ray intensities, the 863 and 647 must be in coincidence with the 912-keV transition. Since the 912, due to its high intensity, must feed the ground state, levels at 912.58, 1560.0, and 1776.5 keV are established. In a test made for transitions whose energy equaled the sum of two other transitions, only a few were found. This lack of "cross-over" transitions and the ambiguity of most of the coincidence results mean that it is not possible to make any further definitive conclusions at the present time.

The isomer also decays by the 334-keV transition to the Te ground state. If one assumes this transition has $M4$ character (see below) an analysis of the transition intensities indicates that none of the levels populated in the decay of ^{133g}Te are populated in the decay of ^{133m}Te, except via the isomeric transition. This conclusion is in agreement with relative γ-ray intensity information in Table III.

Spins and Parities

As in the other $N=81$ isotopes (e.g., ^{135}Xe, ^{137}Ba, ^{139}Ce), the ground state and isomeric state of ^{133}Te are expected to have $I^{\pi}=\frac{3}{2}^{+}$ and $\frac{11}{2}^{-}$, respectively. The isomeric transition should then have $M4$ character. This multipolarity is consistent with the γ-ray intensity balance observed here and the conversion-electron data of Ref. 3. The spin of the ground state of ^{133}I $(Z=53)$ has been measured[11] to be $\frac{7}{2}$ and the parity is presumed to be $+$. Thus, the β transition to the ^{133}I ground state from ^{133g}Te will be second-forbidden $(\Delta I, \Delta\pi = 2, \text{no})$. It is reasonable to suppose that the low-energy states of ^{133}I should be describable in terms of various couplings of the three protons outside the closed shell at $Z=50$.

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[11] *Nuclear Data Sheets*, compiled by K. Way *et al.* (U. S. Government Printing Office, National Academy of Sciences–National Research Council, Washington, D. C.), NRC-61-2-90.

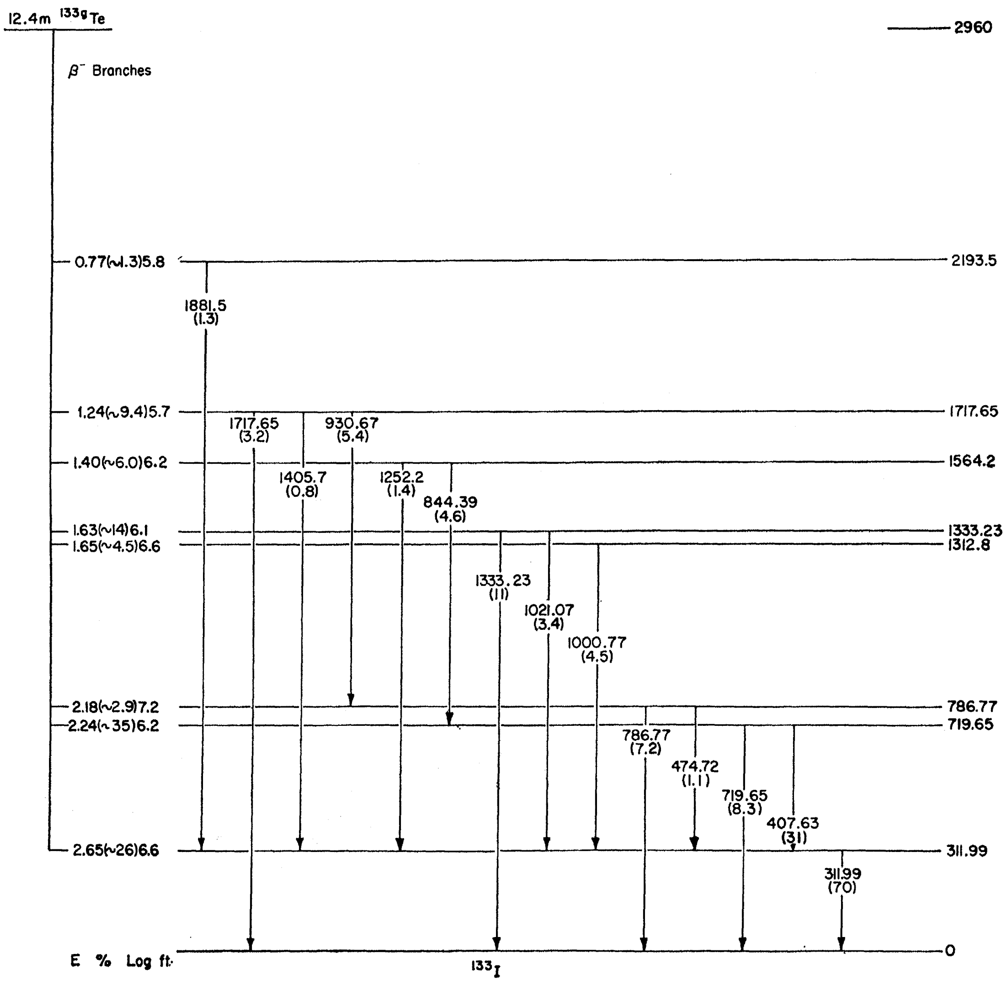

FIG. 10. Proposed decay scheme for ^{133g}Te. γ-ray energies are in keV. The transition intensities, shown in parentheses, are per 100 decays. β transition energies are in MeV. Intensities and log *ft* values are given for each β transition.

Thus, these states are expected to have positive parity. The data presented in this paper do not provide unique spin and parity assignments for the ^{133}I levels observed. Until more definitive data on the levels are available, any attempt at an interpretation of the ^{133}I level structure would at best be ambiguous.

Note added in manuscript. Since the completion of this study, two reports on these isotopes have been submitted for publication. Berg *et al.*[12] have studied the decay of isotopically separated ^{133}Te sources. Parsa *et al.*[13] have conducted experiments similar to those reported in this paper. They did not, however, study the separated ^{133g}Te isomer. Energies and intensities reported in both studies agree well with those reported in this paper.

ACKNOWLEDGMENTS

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APPENDIX

Isomer Separation

For the preparation of ^{133g}Te sources from neutron-irradiated ^{235}U, the gross fission products were dissolved in 20 ml of 3*M* HCl containing 20 mg of Te^{IV} and 2 mg Sb^{III} carriers. After ~4 min from the time of fission, metallic Te was precipitated by the addition of 2 ml of 15% N_2H_4-HCl and SO_2 gas. The precipitate was centrifuged, washed once with 20 ml of 3*M* HCl then dissolved in 1 ml of concentrated HNO_3. After boiling to near dryness, 2 ml of concentrated HBr were added and the solution again boiled to near dryness. A second precipitation of Te metal was made from 20 ml of 3*M*

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[12] V. Berg, K. Fransson, and C. E. Bemis, Jr., Arkiv Fysik (to be published).

[13] B. Parsa, G. E. Gordon, and W. B. Walters, Nucl. Phys. **A110**, 674 (1968).

HCl with N_2H_4-HCl and SO_2 gas. The metal was centrifuged, washed once with water then dissolved with 1 ml of concentrated HNO_3. Excess HNO_3 was removed by boiling and the salts dissolved by heating with 10 ml of water. The solution was cooled under a cold-water tap and 4*M* NH_4OH was added until a precipitate of H_2TeO_3 just started to hold. About 5 ml of 6*M* $NH_4CH_3CO_2$ were added, then the H_2TeO_3 was centrifuged and washed once with water.

About 2 ml of Br_2 water and 2 drops of liquid Br_2 were added to the H_2TeO_3 and the mixture heated to boiling to oxidize Te^{IV} to Te^{VI}. After the removal of excess Br_2 by boiling, the Te^{VI} was taken up in 10 ml of 4*M* HCl and extracted four times, each for 30 sec, with 10 ml portions of 30% tri-*n*-butyl phosphate (TBP) in *n*-heptane.[14] These extractions served to remove excess Br_2 and any unoxidized Te^{IV}. After 30 min, the aqueous phase was again extracted for 1 min with 10 ml of TBP to remove carrier-free ^{133g}Te (as Te^{IV}) which had grown in during that period. The aqueous phase was discarded and the organic was washed three times, each for 30 sec, with 30 ml portions of 6*M* HCl. The ^{133g}Te was removed from the TBP by back extracting for 30 sec with 10 ml of water. To decontaminate from I activities present in the aqueous phase, 20 mg of Te carrier were added and two precipitations of metallic Te were performed as described above. The final Te precipitate was used for analysis. Approximately 15 min were required for the isomer purification.

For the preparation of a near-weightless source of ^{133g}Te for β counting, the above procedure was followed with the following exceptions. Instead of adding Te carrier after the back extraction of ^{133g}Te, 2 mg of Fe carrier were added and the radioactive Te coprecipitated with $Fe(OH)_3$ by the addition of concentrated NH_4OH. The precipitate was centrifuged and washed once with water. The $Fe(OH)_3$ was dissolved in 5 ml of 8*M* HCl and the Fe removed by extracting for 30 sec with 20 ml of isopropyl ether which had been equilibrated with 8*M* HCl. The aqueous phase was removed and boiled to near dryness, 5 drops of concentrated HNO_3 added and the solution again boiled to near dryness. The remaining solution was transferred to a Mylar film (0.7 mg/cm^2) and evaporated to dryness under a heat lamp. Approximately 20 min were required from the time of the isomer separation to the final evaporation on Mylar.

^{133m}Te-^{133g}Te Mixture

In order to obtain mixed sources of ^{133g}Te and ^{133m}Te, the gross fission products were dissolved in a solution comprised of 1 ml of concentrated H_2SO_4 and 2 ml of 3*M* HCl containing 1 mg Sb^{III} carrier. After allowing ~4 min from the time of fission, the solution was introduced into a distillation system described by Greendale and Love.[6] Inert Ar gas was used to force the solution onto Zn metal heated to ~100°C and to flush the evolved SbH_3 gas through a quartz tube. The center of the quartz tube was heated with a Meaker burner. Metallic Sb was deposited as a mirror down stream of the heated area. The quartz tube was immediately removed and the Sb dissolved by flushing with 1 ml of hot concentrated H_2SO_4. The H_2SO_4 was cooled under a cold-water tap and then poured into 20 ml of 3*M* HCl containing 20 mg of Te^{IV} carrier. Two precipitations of metallic Te were made as described above with the final precipitation used for analysis. The time from the SbH_3 distillation to the first Te precipitation was maintained as short as practical (~4 min) to minimize the growth of ^{131g}Te.

When the ^{133m}Te activity was of prime interest, the purified Te obtained from the above method was allowed to decay for 1 h to reduce the ^{131g}Te and ^{133g}Te content. It was then dissolved in concentrated HNO_3, the HNO_3 removed by boiling with concentrated HBr and the Te precipitated as the metal with N_2H_4-HCl and SO_2 gas. This step removes unwanted I daughters formed during the waiting period.

For the preparation of a near-weightless source for 4π β-γ measurements, Se carrier was substituted for Te in the above procedure. Radioactive Te carries on Se metal. Since boiling with HBr removes Se, more carrier was added after such treatment. As a final step, the Se carrier was removed by boiling to dryness with concentrated HBr. The residual radioactive Te was picked up with 2 drops of 1*M* HCl and dried on a plastic film under a heat lamp.

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[14] All TBP used had been previously equilibrated with an equal volume of 4*M* HCl.