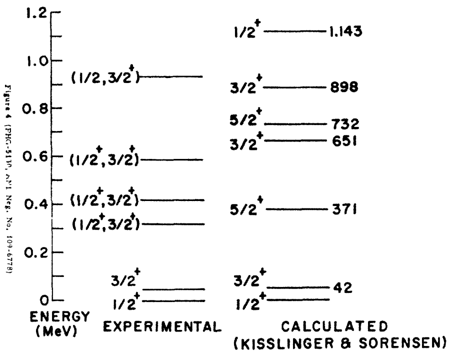

FIG. 4. Comparison of experimental data with results calculated by Kisslinger and Sorensen.

allowed beta decay. The authors see no explanation for this behavior except that the initial state appears to have a large admixture of the $\frac{5}{2}$ quasiparticle configuration.[6]

The recent pairing-model calculations of Kisslinger and Sorensen indicate (Fig. 4) that the six states with spin $\frac{1}{2}$ or $\frac{3}{2}$, obtained by coupling the available quasiparticles to a single phonon, lie below 1.4 MeV. A seventh low-spin state that was indicated by previous results[1] would suggest the need for introduction of additional quasiparticle configurations in calculating the low-energy spectrum; but the existence of this is not confirmed in the present study. Kisslinger and Sorensen predict a $\frac{5}{2}$ state at about 350 keV. Such a level would not be populated directly from Cs^{129} but one might expect to see gamma radiation to it from the higher xenon states of lower spin. No such gamma rays have been observed.

ACKNOWLEDGMENTS

The authors wish to thank T. Gedayloo, W. C. Johnston, and Miss Janet Mather for assistance in collection and analysis of the data. We are also indebted to Dr. L. S. Kisslinger of Western Reserve University for many discussions concerning nuclear theory and especially for supplying calculations of the level structure of Xe^{129} to supplement those in Ref. 6.

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Level Structure of I^{131}

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The levels of I^{131} excited in the decay of the 30-h activity of Te^{131m} have been studied. Scintillation spectrometers were used for recording the gamma spectrum and gamma-gamma coincidences. The internal-conversion spectrum with a double-focusing spectrometer showed K and L lines corresponding to gamma rays of energies 81, 102, and 150 keV and K lines corresponding to 200-, 241-, 336-, 452-, 775-, and 854-keV gamma rays. K conversion lines of 775-, 786-, 797-, 831-, 854-, 869-, 1127-, and 1206-keV gamma rays were observed in the external-conversion spectrum. The relative intensity of the gamma rays was found by analyzing the gamma spectrum and also from the external-conversion spectrum. By use of these relative intensities and the intensities of the internal-conversion lines, the conversion coefficients and the possible multipolarities of the gamma transitions were ascertained. In particular, the 200- and 241-keV transitions were found to be of $E1$ type, indicating the presence of odd-parity states in I^{131}. These two transitions were also found to be highly retarded and the 1829-keV level from which they arise was found to have a half-life of 5.9 ± 0.2 mμsec from delayed-coincidence measurements using a time-to-amplitude conversion technique. From these measurements it is concluded that Te^{131m} decays by beta transitions mainly to the 2012-, 1981-, 1965-, 1931-, and 1902-keV levels of I^{131}. These levels de-excite by transitions to the levels at 1829, 1629, 1583, 1340, 1145, 1065, 797, 775, 602, and 150 keV. From the beta spectrum studied with an intermediate-image spectrometer, it was concluded that the beta transition to the ground state has an end-point energy of 2460 ± 15 keV and a relative intensity of 6%, while the isomeric transition takes place with a relative intensity of 18%.

I. INTRODUCTION

THE levels of I^{131} excited in the decay of the 30-h activity of Te^{131m} have been studied by Hebb[1] and by Badescu *et al.*[2,3] It is known that Te^{131m} has a decay energy of over 2.4 MeV and feeds levels of I^{131} up to about 2 MeV. It also decays by the 182-keV isomeric transition, and the Te^{131} so formed subsequently excites by beta decay the levels of I^{131}. The decay scheme of this 25-min activity of Te^{131} has already been described earlier.[4] In this paper, we report the results of a detailed investigation of the properties of the levels

[1] Elizabeth Hebb, Phys. Rev. **97**, 987 (1955).
[2] A. Badescu, K. P. Mitrofanov, A. A. Sorokin, and V. S. Shpinel, Izv. Akad. Nauk SSSR, Ser. Fiz. **23**, 1434 (1959).
[3] A. Badescu, O. M. Kalinkina, K. P. Mitrofanov, A. A. Sorokin, N. V. Farafontov, and V. S. Shpinel, Zh. Eksperim. i Teor. Fiz. **40**, 91 (1961) [English transl.: Soviet Phys.—JETP **13**, 65 (1961)].
[4] S. H. Devare, P. N. Tandon, and H. G. Devare, Phys. Rev. **131**, 1750 (1963).

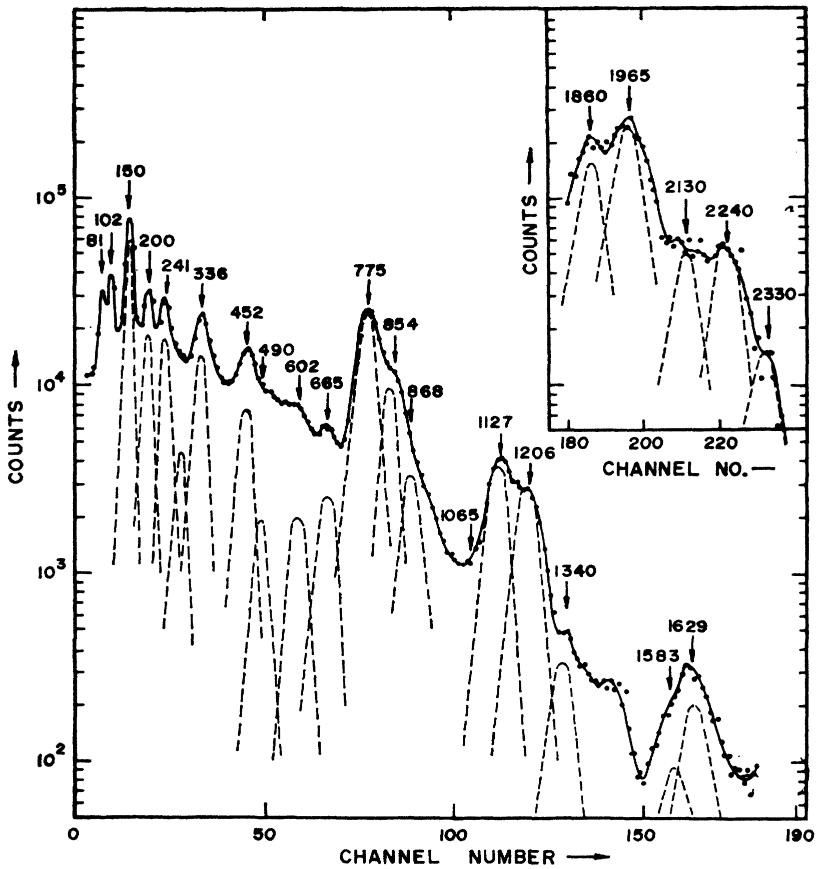

FIG. 1. Gamma spectrum of Te^{131m} taken with a scintillation spectrometer. Inset shows the high-energy part of the spectrum. The energy values have been obtained by combining the results of the spectrum with a solid-state detector and internal- and external-conversion spectra.

of I^{131} excited in the decay of Te^{131m}. These studies were undertaken to remove the discrepancies and the ambiguities in the earlier reports and to have a better understanding of the level structure of I^{131}.

II. EXPERIMENTAL TECHNIQUES AND RESULTS

A. Source Preparation

The sources used for the study of the gamma spectrum, gamma-gamma and beta-gamma coincidences, and delayed coincidences for half-life measurements were obtained by irradiating about 5 mg of enriched Te^{130} (99.5%) in the Canada-India Reactor at Trombay, at a neutron flux of about 8×10^{12} n/cm^2 sec for a period of 4 days. The sources with higher specific activity used for the internal conversion studies were obtained by irradiating the enriched Te^{130} in the DIDO reactor at Harwell at a neutron flux between 1 and 1.5×10^{14} n/cm^2 sec for a similar period. All these sources were chemically purified to remove I^{131} and other impurities. The sources for the double-focusing spectrometer were prepared by electrodeposition on a gold-coated Mylar backing using $1N$ HBr solution of the tellurium activity and a platinum anode in a separated anode compartment.[5] The current used was between 400 μA and 1 mA and the time of deposition between 10 min and 1 h, depending on the desired strength and tolerable thickness of the source. These sources had the dimensions 15 mm$\times$3 mm.

B. Gamma-Ray Spectrum

The gamma-ray spectrum was studied with a scintillation spectrometer. This spectrometer and the method of recording and analyzing the spectra have already been described earlier.[4] Figure 1 shows the gamma spectrum. This was analyzed in the usual manner and the relative intensities of the gamma rays were determined. These are given in Table I. The accurate energy determination of the gamma rays was done from the lines observed in the internal-conversion spectrum. In the case of high-energy gamma rays for which internal-conversion lines could not be observed, the external-conversion spectrum was studied using a 2.3 mg/cm² uranium oxide film as the converter.[6] From this, the exact energies of the 1127- and 1206-keV

[5] A. S. Ghosh-Muzumdar, Proc. Indian Acad. Sci. A48, 106 (1958).

[6] The authors are grateful to Dr. J. H. Hamilton for this external converter.

TABLE I. Relative intensities of gamma rays in the decay of Te^{131m}.

Energy (keV)	Relative intensity[a] Scintillation spectrometer	Ge solid-state detector
81±0.3	5.0	4.0[c]
102±0.3	12.0	9.1[c]
150±0.4[b]	45.0	42.2
200±0.6	17.1	13.3
241±0.8	17.7	13.8
278±2.0	8.1±20%	6.5
336±1.0	21.5	15.4
452±1.0[b]	14.2	13.8
602±1.5[b]	3.6±20%	...
650±10 } 665±2 }[b]	6.0±20%	...
740±10	...	1.5±25%
775±1.0 }	100	79.4 {79.4±10%[d]
786±2 }		20.6 {7.0±15%[d]
797±2 }		{13.6±15%[d]

Energy (keV)	Relative intensity[a] Scintillation spectrometer	Ge solid-state detector	
831±2 }	58	10.2	8 ±25%[d]
854±1 }		41.1	37.5±15%[d]
869±2 }		1.6±25%	
915±2[b]	9.9±20%	6.5±20%	
995±5[b]	4.3±20%		
1050±3	3.7±20%	1.0±25%	
1065±3[b]		2.1±25%	
1127±2		21.8	18.3±20%[d]
1145±2[b]	29.5	6.2	
1206±2	23.7	18.0	
1340±10	2.5±20%	...	
1583±3	2.0±15%		
1629±2			
1860±5	2.0		
1965±3	4.1		
2130±10	0.8±15%		
2240±10	1.0±15%		
2330±15	0.5±20%		

[a] The error, wherever not mentioned, is ±10% for scintillation spectrometer and ±15% for solid-state detector.
[b] These gamma rays occur also in the decay of the 25-min activity of Te^{131}.
[c] Not corrected for the possible absorption in the stainless steel casing of the solid-state detector.
[d] Obtained from the external-conversion spectrum in the double-focusing spectrometer.

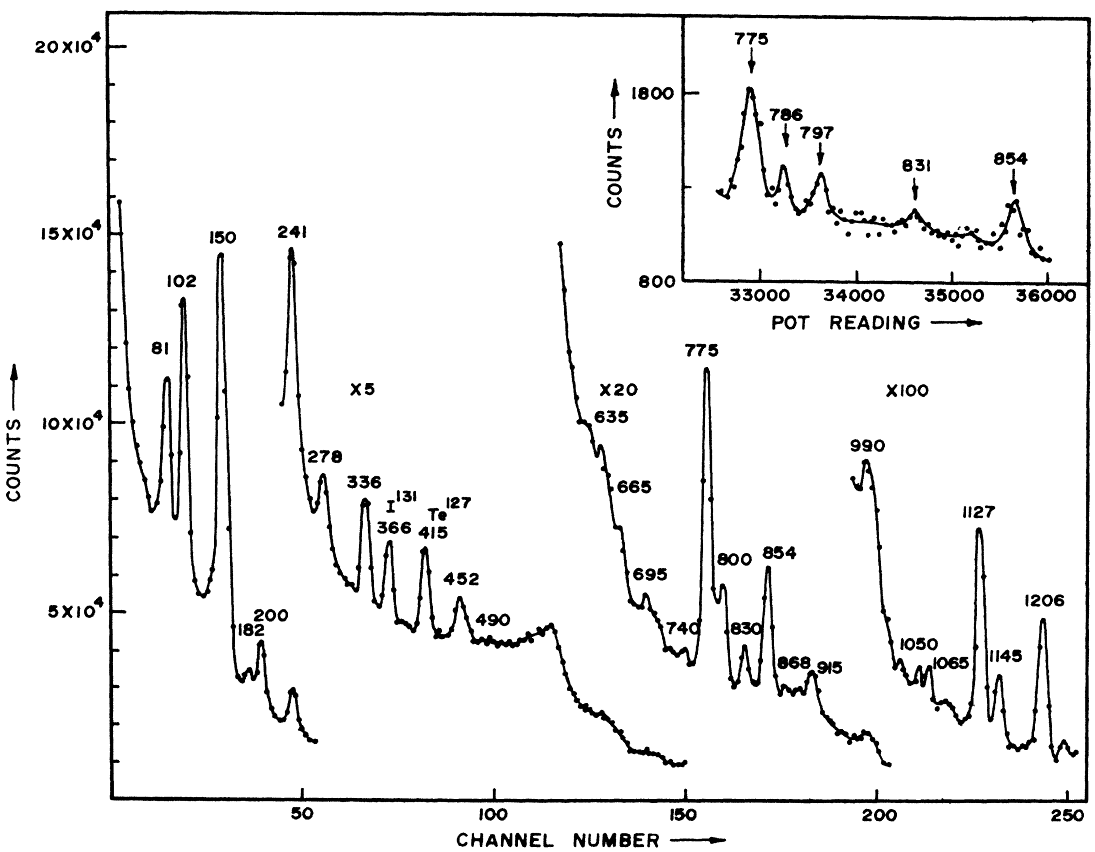

FIG. 2. Low-energy part of the gamma spectrum recorded with a Ge solid-state detector. Inset shows the external-conversion spectrum in the 775- to 854-keV range taken with a double-focusing spectrometer.

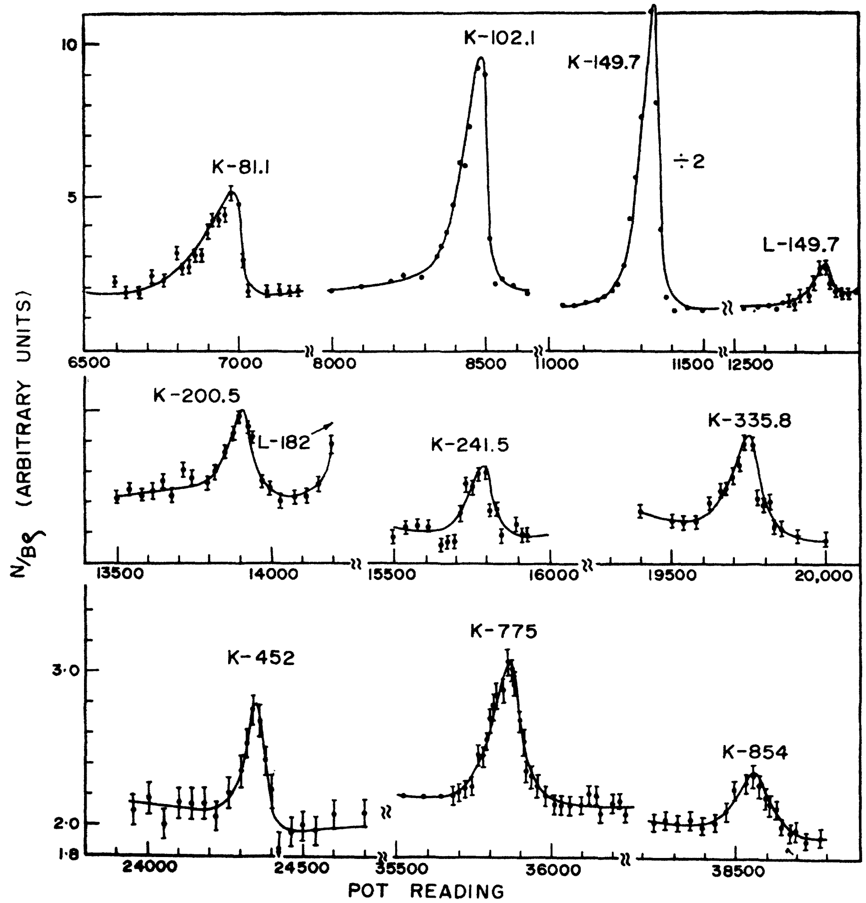

FIG. 3. Internal-conversion spectrum recorded with a double-focusing spectrometer. The L lines of 81.1- and 102.1-keV transitions are not shown. Only a small part of the L line of the 182-keV isomeric transition is shown.

gamma rays and the relative intensities of the 775-, 786-, 797-, 830-, 854-, 1127-, and 1206-keV gamma rays could be found. These are also shown in Table I. When this work was almost complete, a Li-drift germanium solid-state detector became available. This detector had 2-mm depletion depth and gave a resolution of about 9 keV full width at half-maximum (FWHM). The spectrum recorded with this detector is shown in Fig. 2. This spectrum confirms the presence of the 786-, 797-, and 830-keV gamma rays.

C. Internal-Conversion Spectrum

A double-focusing spectrometer with shaped pole pieces was used for the study of the internal-conversion lines. This instrument has been described elsewhere.[7] For the present work, the detector slit width was 3 mm and a resolution of about 0.3% was obtained. No attempts were made to work with better resolution as the highest available specific activity was only about 20 μCi/mg, and it was not possible to make very thin sources. Figure 3 shows the internal-conversion spectra. K and L conversion lines corresponding to gamma rays of energies 81, 102, and 150 keV, and K lines corresponding to 200-, 241-, 336-, 452-, 775-, and 854-keV gamma rays were observed. Several sources were used to record the spectrum, and the relative electron intensities were obtained by using the intensity of the K line of either the 150- or the 775-keV gamma ray for normalization in each case. In the case of 81-, 102-, and 150-keV transitions the absorption in the window of the detector (1.4 mg/cm^2 of mica) was taken into account. The relative electron intensities and the gamma-ray intensities known, the conversion coefficients can be calculated provided the conversion coefficient is known for one of the transitions. In the present case we have calculated the conversion coefficients by assuming the theoretical value[8] for the conversion coefficient of the 150-keV transition. This requires the knowledge of the $E2/M1$ mixing ratio for the 150-keV gamma ray. This was obtained from the measurement of the K/L ratio which could be determined fairly accurately. The conversion coefficients and the possible multipolarities of the various transitions are given in Table II. It may

[7] S. R. Amtey and H. G. Devare, Proceedings of the Nuclear Physics and Solid State Physics Symposium, Chandigarh, 1964, Department of Atomic Energy, India (unpublished).

[8] L. A. Sliv and I. M. Band, in *Gamma Rays* (Academy of Sciences of the USSR, Moscow, 1961).

TABLE II. The conversion coefficients and the multipolarities of some of the gamma transitions.

E_γ (keV)	e^- intensity	α_K (expt)	α_K theoretical $E1$	$E2$	$M1$	K/L (expt)	K/L theoretical $M1$	$E2$	Multipole assignment
81	K, 104 ±15; L, 10.9± 1.6	1.9 ±0.3 (0)	3.2(−1)	2.5(0)	1.6(0)	9.5±2	7.6	1.8	$M1$
102	K, 110 ±13; L, 11.3± 2	8.3 ±1.0 (−1)	1.6(−1)	1.1(0)	6.2(−1)	9.7±2	7.6	2.7	$M1$
150	K, 100 ±3; L, 14.7± 0.7	2.05±0.07(−1)	5.3(−2)	3.2(−1)	2.0(−1)	6.8±0.3	7.6	4.0	$M1$+12±5% $E2$
200	K, 5.9± 0.8	3.1 ±0.5 (−2)	2.4(−2)	1.3(−1)	9.3(−2)	···	···	···	$E1$, ⩽7% $M2$
241	K, 3.2± 0.6	1.7 ±0.5 (−2)	1.5(−2)	6.6(−2)	5.6(−2)	···	···	···	$E1$, ⩽7% $M2$
336	K, 6.1± 0.9	2.6 ±0.5 (−2)	6.2(−3)	2.3(−2)	2.4(−2)	···	···	···	$M1$, $E2$
452	K, 1.5± 0.3	1.0 ±0.25(−2)	3.0(−3)	9.0(−3)	1.1(−2)	···	···	···	$M1$, $E2$
775	K, 1.9± 0.3	2.2 ±0.4 (−3)	8.0(−4)	2.3(−3)	3.1(−3)	···	···	···	$E2$, ⩽30% $M1$
854	K, 1.0± 0.3	2.2 ±0.5 (−3)	7.0(−4)	1.8(−3)	2.5(−3)	···	···	···	$E2$, $M1$

be mentioned here that the conversion coefficient for the 775-keV transition was also found by internal-external conversion (IEC) method to be $\alpha_k=(1.8\pm0.6)\times10^{-3}$ which agreed well with the value given in Table II, supporting the procedure adopted for these calculations. Our value of α_k for the 775-keV gamma ray shows it to be a predominantly $E2$ transition whereas Badescu *et al.*[3] had considered it to be $E1$ on the basis of their measurement of α_k. This disparity may be attributed to the poor resolution of the spectrometer used by them. Another interesting feature is the $E1$ character of the 200- and 241-keV transitions which indicates the presence of negative-parity states in I^{131}.

D. Gamma-Gamma Coincidence Measurements

The coincidence measurements were made with two scintillation spectrometers consisting of 3-in.-diam ×3-in.-thick NaI (Tl) crystals coupled to DuMont 6363 photomultipliers. When coincidences with low-energy gamma rays were studied, a smaller crystal, 1½ in. diam×1 in. thick, mounted on DuMont 6292 photomultiplier was used. The coincidence circuit was of the cross-over pick-off type[9] and had a resolving time $2\tau=150$ mμ sec. In general, face-to-face geometry was used, the usual shielding precautions being taken to avoid spurious coincidences. Whenever it was desired to avoid the summing effects, the measurements were made either with right-angle geometry with a larger source-to-crystal distance or with lead absorbers of suitable thickness in cases where only the high-energy gamma rays were of interest. The complexity of the gamma spectrum made it necessary to select very narrow gates. The gate position was shifted in small steps so as to scan almost the entire gamma spectrum and the coincident spectra for the various gate positions were recorded on a multichannel analyzer. The coincidences due to the Compton contributions of various gamma rays included in the gate could then be taken into account by analyzing these coincidence spectra. Some of the important coincidence spectra are reproduced in Figs. 4, 5, and 6. The gamma energies mentioned there and in what follows were inferred from the measurements with the double-focusing spectrometer. The chance contribution was <5% and was corrected for.

[9] E. Fairstein, Oak Ridge National Laboratory Report No. 2480, 1958 (unpublished).

It can be seen from Fig. 4, curves A and B, that the 81- and 102-keV gamma rays are in coincidence with each other and also with the 200- and 241-keV gamma rays. The 81-keV transition, moreover, shows coincidence with the 1127-keV gamma ray, while the 102-keV transition does not show this coincidence but is in coincidence with a 1050-keV gamma ray. Both the 81- and 102-keV gamma rays show similar coincidence spectra in the region of the photopeaks at 775 and 854 keV. With the photopeak of the 200-keV gamma ray (curve D) one gets in coincidence gamma rays of energies 775, 854, and 1629 keV while the photopeak of the 241-keV gamma ray (curve C) gives coincidences with gamma rays of energies quite close to 775 keV and also with a relatively weak 1583-keV transition. The 336-keV gamma ray is in coincidence with the 775-, 854-, and 1629-keV transitions (curve E). It may be noted here that 854–775 keV is a very intense cascade in the decay of Te^{131m} and so the photopeaks at 775 and 854 keV appearing in all the coincident spectra are partly due to the acceptance in the gate of the Compton contribution of these gamma rays. These coincidences have been interpreted on the basis of levels in I^{131} at 775±1, 1583±3, 1629±2, 1829±3, 1931±4, 1965±3, and 2012±5 keV. The 1629-keV level de-excites by the 854–775-keV cascade as well as the 1629-keV gamma ray and is fed from the 1829- and 1965-keV levels by the 200- and 336-keV transitions, respectively. The 1931-keV level is fed from the 2012-keV level by the 81-keV transition and de-excites to the 1829-keV level by the 102-keV transition. The 241-keV gamma ray also arises from the 1829-keV level and feeds a level at 1583 keV. This level de-excites by a 1583-keV gamma ray and a 786–797-keV cascade through a level at 797 keV. The 786- and 797-keV gamma rays have been observed quite well resolved in the external-conversion spectrum and as a composite peak in the

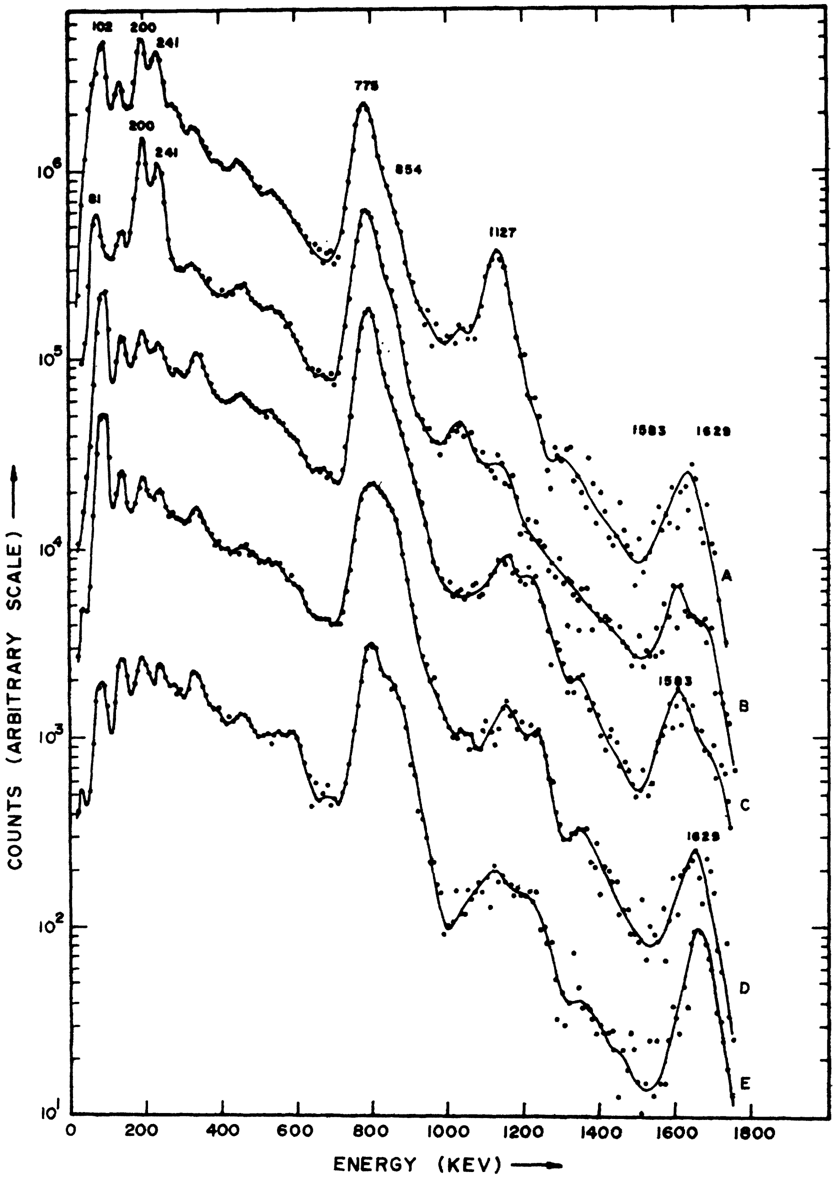

FIG. 4. Gamma spectrum in coincidence with the photopeaks of A: 81-keV, B: 102-keV, C: 241-keV, D: 200-keV, and E: 336-keV gamma rays.

gamma spectrum taken with the solid-state detector. They could not be resolved from the 775-keV photopeak in the coincidence work with scintillation spectrometers. Besides the 200- and 241-keV gamma rays, the 1829-keV level also de-excites by a 1050-keV gamma ray to the 775-keV level. The energies of the proposed levels and of the gamma transitions between them are consistent within the errors of measurements.

The coincidences with 775-, 854-, 915-, and 1127-keV regions of the spectrum are shown in Fig. 5. It is clear that the 775-keV gamma ray is in coincidence with the 854-, 1127-, and 1206-keV gamma rays (Fig. 5, curve A). The 854-keV gamma ray is not in coincidence with either the 1127- or the 1206-keV transition, the peak around 1140 keV being due to a 868–1145-keV cascade (curve B). The 915-keV region of the spectrum is in coincidence with a gamma ray of almost the same energy and also a 1065-keV gamma ray (curve C). As expected from the coincidence measurements and their interpretation described above, the 854-keV photopeak shows a strong coincidence with the 200-keV transition, while the 775-keV photopeak has a relatively stronger coincidence with the 241-keV transition. This point was verified by recording the coincidence spectra with various narrow regions of the 775- 854-keV composite photopeak in gate. Similarly the 854-keV photopeak is not more intense than the 775-keV photopeak as one would expect it to be in the spectrum in coincidence with the 775-keV photopeak. This is also because of the inclusion of 786- and 797-keV photopeaks in the

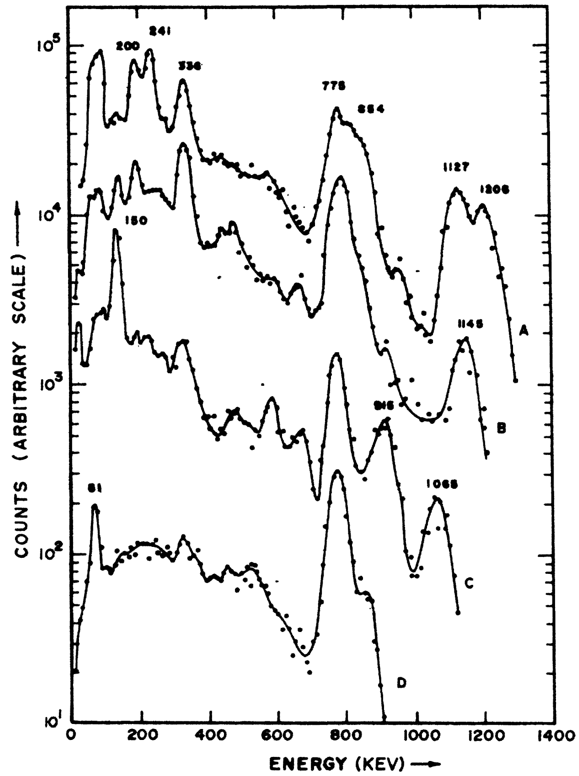

FIG. 5. Gamma spectrum in coincidence with A: 775-keV, B: 854-keV, C: 915-keV, and D: 1127-keV regions.

gate, and also partly due to the Compton contribution of various gamma rays which are in coincidence with the 775-keV transition. The coincidence of 1127- and 1206-keV transitions with the 775-keV gamma ray requires additional levels at 1902±3 and 1981±3 keV. The coincidence between the 81- and the 1127-keV transitions (curve D) can then be understood only by postulating a 29-keV transition between the 1931- and 1902-keV levels. Such a transition would be highly converted and very difficult to observe. It was not possible to obtain any other evidence in support of this transition. The coincidence of 915 keV with 915- and 1065-keV gamma rays is interpreted by postulating a 915-keV transition between the 1981-keV level and the 1065-keV level which is already known from the decay of the 25-min activity of Te^{131}. The 1065-keV was shown[4] to de-excite only by the 915–150-keV cascade and the 1065-keV ground-state transition could not be observed in the earlier work because of the presence of the relatively intense 1145-keV gamma ray. It has been possible to observe the 1065-keV transition in the present work only in coincidence spectra.

Figure 6 shows coincidence spectra with the photopeaks of 150- and 452-keV gamma rays and 660- and 730-keV regions of the spectrum. It is seen that there are gamma transitions to the previously established 602-keV level. In order to explain the occurence of 665- and 1340-keV gamma rays and also the coincidence of 665-keV gamma rays with 150-, 452-, 602-, 740-, and 1340-keV transitions (Fig. 6, curve C) a level has been postulated at 1340 keV which is fed by a 665-keV gamma ray from the 1981-keV level. This 1340-keV level de-excites by a 1340-keV ground-state transition and a 740-keV gamma ray to the 602-keV level. The results of all the coincidence measurements are summarized in Table III.

E. Delayed Coincidence and Lifetime Measurements

In order to check whether any of the levels has a measurable half-life, the gamma spectrum in delayed coincidence with low-energy beta rays was recorded. For these measurements $1\frac{3}{4}$-in.-diam×2-in.-thick NaI (Tl) and 1-in.-diam×$\frac{1}{4}$-in.-thick anthracene crystals mounted on RCA 6810A photomultipliers were used. A modified Green and Bell-type[10] time-to-amplitude converter (TAC) was used for lifetime measurements and also as a fast coincidence circuit. The beta spectrum in the region of 300 to 400 keV was selected in the gate and the gamma spectrum in delayed coincidence was scanned on the multichannel analyzer. The gating pulses for the multichannel analyzer corresponding to delayed and not prompt beta-gamma coincidences were obtained

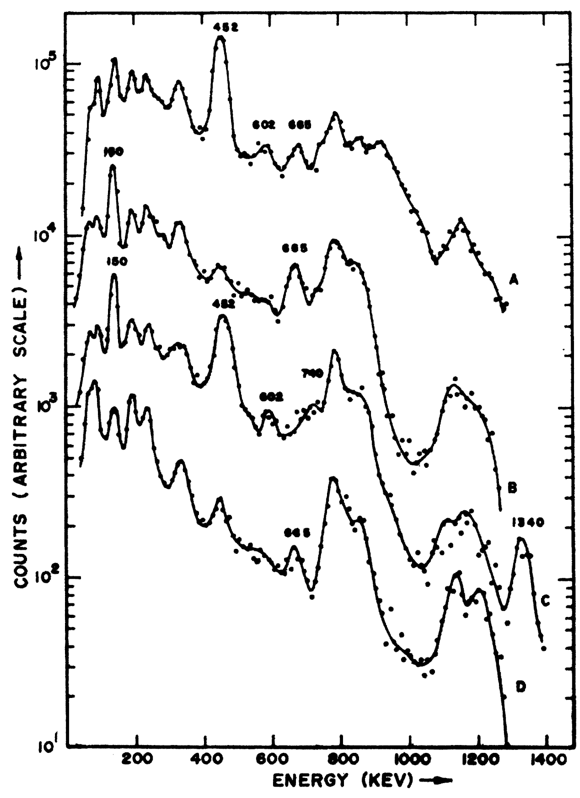

FIG. 6. Gamma spectrum in coincidence with A: 150-keV, B: 452-keV, C: 660-keV, and D: 730-keV regions.

[10] R. E. Green and R. E. Bell, Nucl. Instr. 3, 127 (1958).

by amplifying the pulses from the TAC and selecting by single-channel analyzer only those pulses from the TAC spectrum which corresponded to the desired delay. The output of this single-channel analyzer was fed to the triple slow-coincidence circuit from which the gating pulses for the multichannel analyzer were obtained. This delayed-coincidence spectrum showed photopeaks corresponding to 200-, 241-, 775-, 854-, and 1050-keV gamma rays. These gamma rays are known from coincidence measurements to be emitted in the de-excitation of the 1829-keV level and so this level is expected to have a lifetime of a few mμ sec. This point was also checked by scanning the gamma spectrum in delayed coincidence with the 102-keV transition. For this purpose the anthracene crystal was replaced by a NaI(Tl) crystal. This spectrum is shown in Fig. 7, which also shows the prompt-coincidence spectrum for comparison. The photopeaks corresponding to the 200-, 241-, 775-, 854-, and 1050-keV gamma rays arising from the 1829-keV level can be clearly identified here. A spectrum of gamma rays preceding the 200- and 241-keV transitions was also recorded by the same delayed-coincidence technique and only the 81- and 102-keV photopeaks were observed. This confirms the conclusion from the gamma-gamma coincidences that the 81-keV–102-keV cascade lands on the 1829-keV level.

The half-life of the 1829-keV level was measured by recording the delayed beta-gamma and gamma-gamma coincidence curves on a multichannel analyzer. Figure 8 shows the curve for the 102-keV–200-keV cascade taken with NaI(Tl) crystals using the same setup as described above. From the slope of this curve, the half-life of the 1829-keV state is seen to be 5.9±0.2 mμ sec. The error is mainly due to the uncertainty in the time calibration of the TAC which was done by introducing delays by means of cables of known length

TABLE III. Results of gamma-gamma coincidence measurements.

Gate (keV)	Gamma rays in coincidence (keV)
81	102, 200, 241, (775+786+797), (830+854), 1050, 1127, (1583+1629)
102	81, 200, 241, (775+786+797), (830+854), 1050, (1583+1629)
150	452, 670, 740, 915, 995, 1865
200	81, 102, (775+797), (830+854), 1629
241	81, 102, (775+786+797), 1583
278	336, (775+797), (830+854), 1629, 1965
336	278, (775+797), (830+854), 1629
452	150, 665, 740
665	150, 452, 602, 740, 1340
740	150, 452, 602, 665
(775+786+797)	81, 102, 200, 241, 336, (786+797), (830+854), 1050, 1127, 1206
(830+854+869)	81, 102, 150, 200, 336, (775+797), 995, 1145
915	150, 915, 1065
(1127+1145)	81, 775, 869

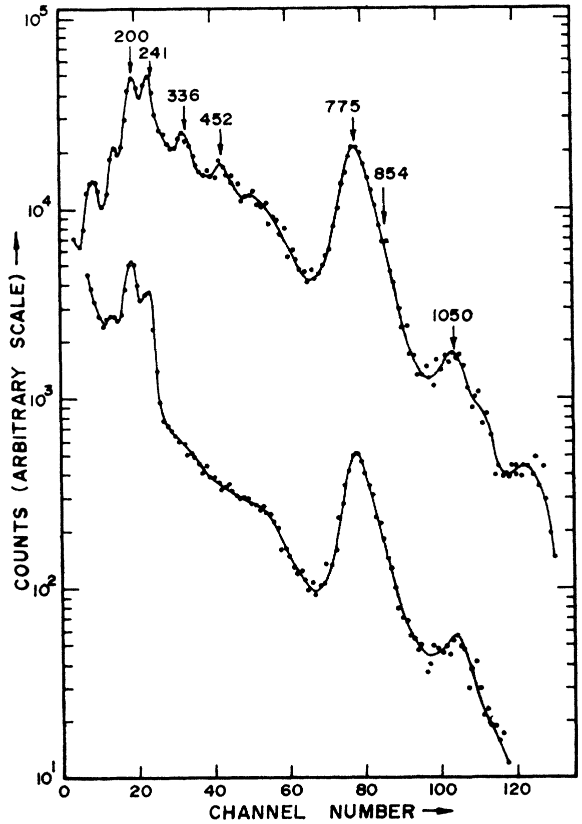

FIG. 7. Gamma spectrum in delayed coincidence (lower curve) and prompt coincidence (upper curve) with the 102-keV transition. The delay corsesponds to 8 mμ sec in the 500-keV region.

and observing the shift in the peak position of the prompt-coincidence curve obtained with the Na^{22} source.

The half-life of the 150-keV state was also measured by the same technique except that a plastic scintillator was used to detect the 150-keV gamma ray. The measurements were made with the 25-min activity of Te^{131} so that the rather long half-life of the 1829-keV state did not cause any interference. The delayed-coincidence curve for the 452–150-keV cascade is shown in Fig. 8, which also shows the prompt curve obtained with a Na^{22} source for the same energy region. The prompt-coincidence curve has a FWHM of 1.5 mμ sec and a slope of 0.4 mμ sec. The half-life of the 150-keV state is found to be 0.95±0.05 mμ sec, in good agreement with the value reported by de Waard and Gerholm.[11] The same value was obtained by delayed beta-gamma coincidence measurements.

F. Beta Spectrum and Beta-Gamma Coincidence Measurements

The beta spectrum was studied with a Siegbahn-Slätis intermediate-image spectrometer at 2% resolu-

[11] H. de Waard and T. R. Gerholm, Nucl. Phys. 1, 281 (1956).

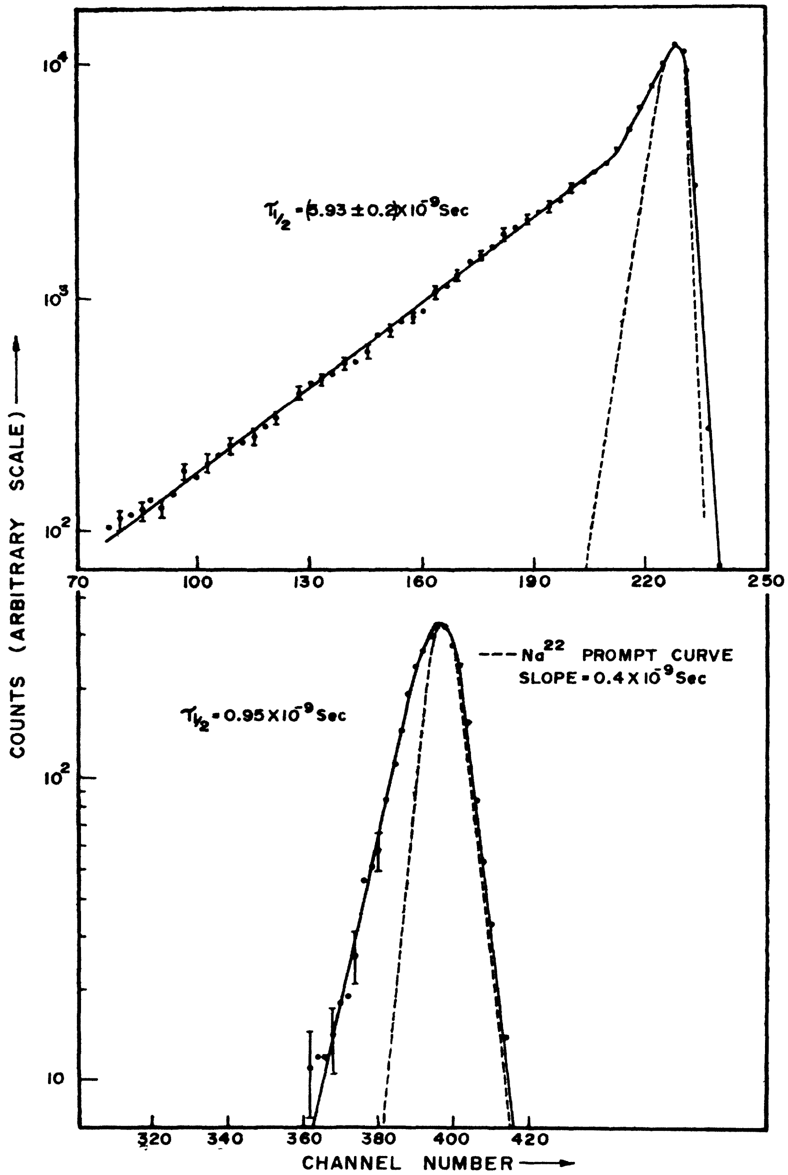

FIG. 8. Delayed-coincidence curve for the 102–200-keV cascade (upper curve) and the 452–150-keV cascade (lower curve). The prompt-coincidence curve in each case is shown by the dashed line.

tion. Comparison of the areas of the total beta spectrum and the K and L internal-conversion lines due to the 182-keV isomeric transition showed that the branching ratio for the isomeric transition is 18%. This is the same as the value reported in Ref. 3. Fermi analysis of the beta spectrum showed that the beta transition from Te^{131m} to the ground state of I^{131} has an end-point energy of 2460 ± 15 keV. The branching ratio for this beta transition was found to be 6% by comparing its intensity with that of the beta transition from Te^{131} to the 150-keV state and using the relative intensities of the various beta groups in the decay of Te^{131} as given in Ref. 4. This leads to the logft value of 9.2 for this transition.

Beta-gamma coincidences were studied with the same setup described in Sec. IID above, using an anthracene crystal for detecting the beta particles. These measurements showed that the levels at 775, 1583, 1629, and 1829 keV do not have any beta feeding. The levels at 2012, 1981, and 1931 keV have beta feeding with a logft of about 6 as determined from the relative intensities of the gamma rays which land on and which arise from these levels. Similarly, the logft value for the beta transitions to 1902- and 1965-keV levels is about 6.5. These logft values are not expected to be very accurate as the possibility of highly converted transitions in between these levels, which would be difficult to observe, cannot be ruled out. The relative intensities of the beta groups could not be obtained from the Fermi analysis of the beta spectrum as the

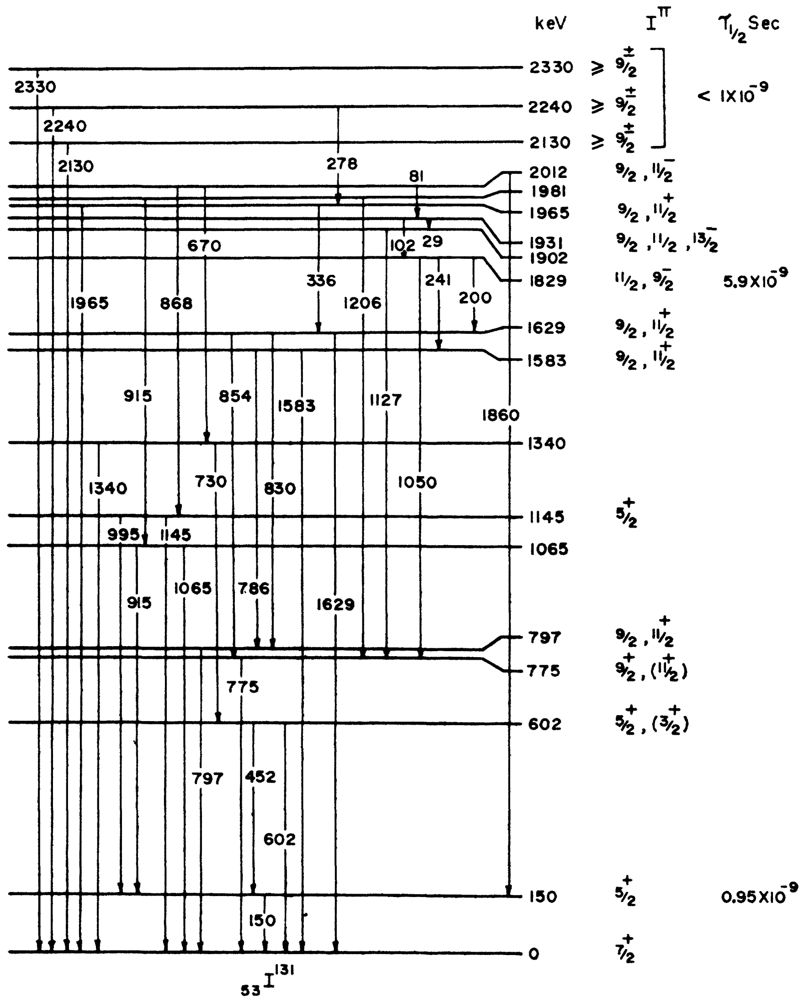

FIG. 9. Levels of I^{131} excited in the decay of Te^{131m}.

levels lie very close to each other and the end points of the various beta groups differ only by a very small energy.

G. The Level Scheme and Discussion

The gamma transitions and their coincidence relationships observed in the decay of Te^{131m} have been interpreted on the basis of levels in I^{131} at 150, 602, 775, 797, 1065, 1145, 1340, 1583, 1629, 1829, 1902, 1931, 1965, 1981, 2012, 2130, 2240, and 2330 keV. The decay scheme is shown in Fig. 9. The energies of the gamma transitions as determined from the internal- and external-conversion spectra have been used to get the accurate energies of the levels wherever possible. The levels at 150, 602, 1065, and 1145 keV are known from the decay of Te^{131}. In the decay of Te^{131m}, these levels are excited only by rather weak gamma transitions from the higher levels. The levels at 2130, 2240, and 2330 keV have been postulated because of the observed gamma rays of these energies. It was seen from a total-absorption gamma-ray spectrum taken with a well-type NaI(Tl) crystal that these gamma rays do not sum up with the 150-keV transition, showing that these are all ground-state transitions. The other excited states and the gamma transitions among them have already been considered in Sec. II D above.

The spin and parity assignments for the ground state and the 150-keV first excited state of I^{131} are $\frac{7}{2}^+$ and $\frac{5}{2}^+$, respectively, corresponding to the $g_{7/2}$ and $d_{5/2}$ shell-model orbitals. The logft values of the beta transitions to these from Te^{131m} and Te^{131} are consistent with these assignments and the $h_{11/2}$ and $d_{3/2}$ character of Te^{131m} and Te^{131}, respectively. The observed half-life, the $E2/M1$ mixing ratio, and the conversion coefficient for the 150-keV transition show that the $M1$ part of the transition is retarded by a factor of about 300 compared with the single-particle estimate. This retardation may be attributed to the l-forbidden nature of this transition or to the phonon admixture in the 150-keV state.[12] The $E2$ enhancement for this transition

[12] R. A. Sorensen, Phys. Rev. **132**, 2270 (1963).

by a factor of almost 130 over the single-particle estimate points to a considerable phonon admixture.

Some information about the parities of the other excited states can be obtained from the multipolarities of some of the transitions as determined from the conversion coefficient measurements. Thus the 81- and 102-keV transitions are $M1$, the 200- and 241-keV transitions are $E1$, and the 336-, 775-, and 854-keV transitions are $M1+E2$. This leads to the conclusion that the parity of the 775-, 1583-, 1629-, and 1965-keV states is even while that of the 1829-, 1931-, and 2012-keV states is odd. As the multipolarities of the 1127- and 1206-keV transitions could not be fixed, it is not possible to come to any conclusion about the parity of the 1902- and 1981-keV levels. The beta transitions to these levels also do not give any information about the parity as the uncertainty in the $\log ft$ value of the beta transitions makes it difficult to decide unambiguously whether the transitions are allowed or first forbidden.

The spin of the 775- and 797-keV levels could be $\frac{9}{2}$ or $\frac{11}{2}$, the assignment $\frac{7}{2}$ being rather unlikely as these levels would then have first-forbidden unique beta transitions with $\log ft$ values around 8, which are not observed. The 1065- and 1145-keV states have allowed beta feeding from Te^{131}. In view of this and the gamma transitions to these states from the 1981- and 2012-keV levels which have spins $\geqslant \frac{9}{2}$, the most probable assignment for the 1065- and 1145-keV states would be $\frac{5}{2}^+$. The spin assignments to the other levels indicated in the figure have been made on similar considerations of beta and gamma transitions involving these levels

The excited states of I^{131} are expected to have admixtures from the one- and two-phonon states of the core. It is known[13] that the one-phonon 2^+ state of Te^{130} is at 846 keV while the two-phonon states occur at 1588 (4^+) and 1633 (2^+) keV. It seems likely that the 775- and 797-keV levels of I^{131} have one-phonon admixture while the 1583- and 1629-keV levels have admixtures from the two-phonon states of the core. This is supported by the fact that the 1583- and 1629-keV levels de-excite mainly by cascades through the 775- and 797-keV levels, and the cross-over transitions are relatively weak.

The odd-parity states could arise as a result of the excitation of the odd proton of the $h_{11/2}$ orbital which is expected to lie at about 2 MeV. This interpretation for the 1829-, 1931-, and 2012-keV levels can explain the very large retardation of the $E1$ transitions from the 1829-keV level, provided all the lower excited states have mainly $d_{5/2}$ and $g_{7/2}$ proton configuration. The absence of any beta feeding to this level is rather difficult to understand as Te^{131m} is an almost pure $h_{11/2}$ neutron quasiparticle state and the $(U_nU_p)^{-2}$ factor due to pairing correlation[14] is not large enough to increase the $\log ft$ sufficiently. Another possible interpretation for the odd-parity states would be that they are three quasiparticle excitations corresponding to a $g_{7/2}$ or $d_{5/2}$ proton configuration and a $(h_{11/2}, d_{3/2})$ neutron configuration. Such a breaking of the neutron pair would be analogous to the two quasiparticle 5^- and 7^- states in Sn^{120} and Sn^{118}.[15] The $E1$ transitions from the 1829-keV state, in this case, are $h_{11/2} \rightarrow d_{3/2}$ neutron transitions and are expected to be highly retarded because of their l as well as j forbiddenness.

Odd-parity states can also arise as a result of the coupling of the particle motion to the octupole vibrational state of the core. The 3^- state in Te^{130} has not been established so far but is expected to be around 2.4 MeV where the 3^- state of Te^{126} is known to occur.[13] However, it is not possible to identify any of the levels with this type of excitation as there is no evidence for enhanced $E3$ transitions which characterize such excitations.

Exact interpretation of these levels will have to wait till unambiguous spin assignments and multipolarities of the gamma transitions become available from γ-γ and e^--γ angular-correlation studies.

Note added in proof. The three quasiparticle nature of the 1829-keV state is further supported by the measurement of its g factor[16] which shows that $g=-0.14\pm0.05$. The negative sign and the very small value of g rule out the possibility of this state being a $h_{11/2}$ proton excitation and indicate a configuration of the type

$$(g_{7/2}p,\ d_{3/2}n,\ h_{11/2}n) \quad \text{or} \quad (d_{5/2}p,\ d_{3/2}n,\ h_{11/2}n).$$

ACKNOWLEDGMENTS

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[13] J. A. Cookson and W. Darcey, Nucl. Phys. **62**, 326 (1965).

[14] L. S. Kisslinger and R. A. Sorensen, Rev. Mod. Phys. **35**, 853 (1963).

[15] H. Ikegami and T. Udagawa, Phys. Rev. **124**, 1518 (1961).

[16] P. N. Tandon and H. G. Devare (to be published).