Disintegration of Te^{121} and Te^{123} Isomers*

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(Received December 29, 1949)

Line intensities in the conversion electron spectra of Te^{121} and Te^{123} were evaluated in a variable field, 180° focusing beta-ray spectrograph. Electron-electron coincidences were obtained between the transition pairs 82–213 kev in Te^{121} and 88.5–159 kev in Te^{123}. Decay schemes for the two isomers are shown.

INTRODUCTION

THE disintegration of Te^{121} and Te^{123} isomers has been studied (a) through the activity of the tellurium fraction chemically separated from deuteron bombarded antimony and, (b) through the activity induced by pile bombardment of a Te sample enriched in Te^{122}. Sources of type (a) had been shown to exhibit: a 120–143 day activity;[1,2] a 16–17 day activity[2] interpreted as K-capture from the ground state of Te^{121} to the 610 kev excited state[3] of Sb^{121}; a "two-step" isomeric transition;[3,4] conversion electrons corresponding to 82, 88.5, 159, and 213 kev transitions.[5] Conversion electrons corresponding to 88.5 and 159 kev transitions were found in a type (b) source.[6]

We have sought to establish that both isomers, Te^{121} and Te^{123}, decay to the ground state in two steps by showing that there are coincidences between transitions. In order to aid in the construction of a decay scheme we also endeavored to determine the conversion coefficients.

COINCIDENCE MEASUREMENTS

By means of coincidence measurements in a "double slit" beta-ray spectrograph, electrons from the 82 and 213 kev transitions were shown to be in coincidence with each other. Similarly conversion electrons from the 88.5 and 159 kev transitions were also shown to be in coincidence. Coincidence rates obtained were 1.4±0.05 c/m for the former pair and 3.3±0.13 c/m for the latter pair with chance rates of 0.03 and 0.04 c/m, respectively. As different slit openings were used in these two determinations, the rates are only illustrative of magnitude of coincidences which can be achieved in a "double-slit" beta-ray spectrograph. The spectrograph insert used for these experiments is shown in Fig. 1. A different type of "double-slit" spectrograph has been previously described by Feather, Kyles and Pringle.[7]

Electron-gamma coincidences were also measured with a similar arrangement to Fig. 1, except that the gamma-ray counter was mounted directly behind the source. These experiments showed the existence of 159

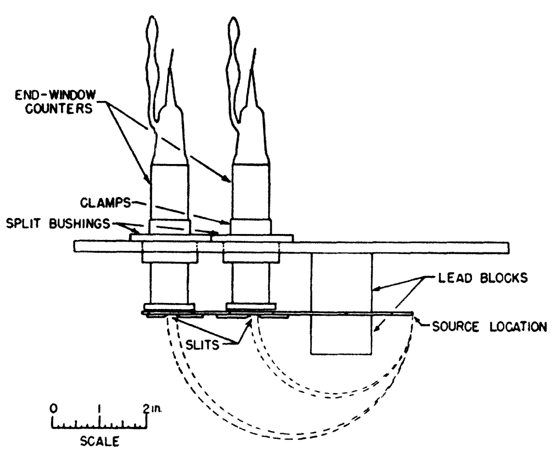

FIG. 1. Electron-electron coincidence insert.

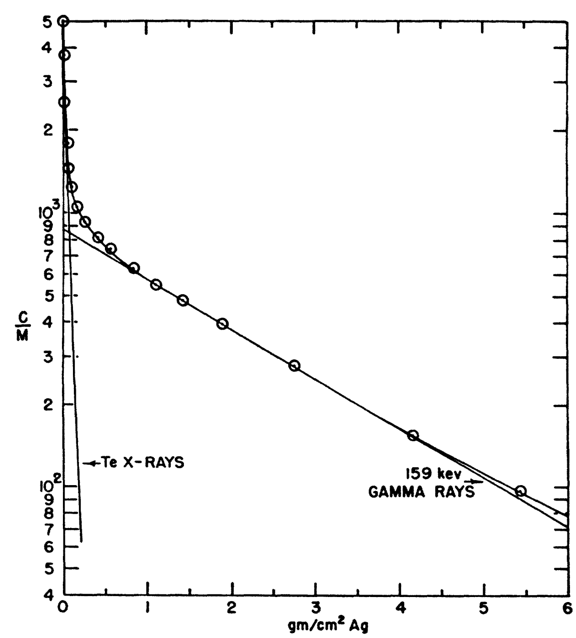

FIG. 2. Silver absorption of Te^{123} x-rays and gamma-rays.

* Assisted by the Joint Program of ONR and AEC.
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[1] Seaborg, Livingood, and Kennedy, Phys. Rev. **57**, 363 (1940).
[2] J. E. Edwards and M. L. Pool, Phys. Rev. **69**, 140 (1946).
[3] Burson, Bittencourt, Duffield, and Goldhaber, Phys. Rev. **70**, 566 (1946).
[4] Bittencourt and M. Goldhaber, Phys. Rev. **70**, 780 (1946).
[5] R. D. Hill and J. W. Mihelich, Phys. Rev. **74**, 1847 (1948).
[6] R. D. Hill, Phys. Rev. **76**, 333 (1949).
[7] Feather, Kyles, and Pringle, Proc. Phys. Soc. London **61**, 466 (1948).

TABLE I. Relative intensities of conversion lines of Te^{121} and Te^{123}.

Isomer	Conversion line	Area under line (arbitrary units)	Peak height (arbitrary units)	Relative* intensity
Te^{121}	82-K	3420±850	306±26	75
Te^{121}	82-L	3930±980	473±26	100
Te^{121}	82-M	560±140	107±32	18
Te^{121}	213-K	371±37	108±7	16
Te^{121}	213-L	53±5	14±5	2.2
Te^{123}	88.5-K	2430±600	253±23	57
Te^{123}	88.5-L	3510±880	374±25	84
Te^{123}	88.5-M	560±140	115±21	19
Te^{123}	159-K	600±60	153±8	24
Te^{123}	159-L	61±6	19±8	2.8

* *Note:* The relative intensities of the lines of Te^{121} compared to those of Te^{123} are significant only for a particular source and change with time due to the different decay periods of the two isomers.

and 213 kev gamma-radiation in coincidence with electrons from the 88.5 and 82 kev transitions, respectively. The existence of the unconverted 159 kev gamma-radiation, which had previously not been reported, was demonstrated by absorption of the gamma radiation from the source (b). Figure 2 shows the absorption of the 159 kev gamma-ray in silver. There is no indication of the 88.5 kev gamma-rays, and one can conclude that this transition is nearly completely internally converted.

Since Hill and Mihelich[5] had observed conversion lines which might be interpreted as L and M lines of a 36.5 kev transition, we also looked for unconverted 36.5 kev gamma-rays in both Te^{121} and Te^{123}. Using a xenon-filled counter to emphasize radiation of this energy and by means of matched barium and iodine absorbers we could show that, if present, this gamma-radiation was of intensity less than two percent of the total x- and gamma-radiation of either source.

ELECTRON INTENSITY MEASUREMENTS

The conversion electron spectrum of a type (a) source was studied in a variable field, 180° focusing beta-ray spectrometer with a thin end window counter (0.9 mg/cm^2 mica) as detector. The spectrum obtained is shown in Fig. 3. Window correction data were obtained by placing a sheet of mica (1.9 mg/cm^2) over the counter and re-determining the peak intensities of the conversion lines. The correction data were in good agreement with the published curve of Feather, Kyles, and Pringle.[7] Line intensities were obtained by averaging the relative intensities obtained by two methods of evaluation. It has been shown by Lawson and co-workers[8,9] that both the peaks of the experimental lines, and the areas under the normalized lines (that is, the experimental data divided by the focusing magnetic field) should yield identical results. A complication, however, is introduced by scattering. Source scattering removes electrons from the peaks, and scattering from the source backing adds electrons to the low energy tails. Thus relative intensities determined on peak analysis may be expected to be too low, while values based on area analysis may be too high. The average values of the relative line intensities obtained by the two methods of analysis may be expected to be closer to the true values and these are shown in Table I. These values were used to compute conversion coefficients and N_K/N_L ratios. Computation of the conversion coefficients was based on the assumption of complete conversion of the parent 82 and 88.5 kev transitions. A separate investigation of the spectrum (not shown in Fig. 3) was made to determine the intensity of conversion electrons of the 610 kev transition in Sb^{121}.

The comparison of experimental and theoretical results is given in Table II. In general, they confirm the earlier observations based on photographic intensity measurement.[5,6] However, the conclusions with regard to the 213 kev transition are notably clearer. For the 159 and 213 kev transitions the K-shell conversion coefficients are consistent with purely 2^1 magnetic radi-

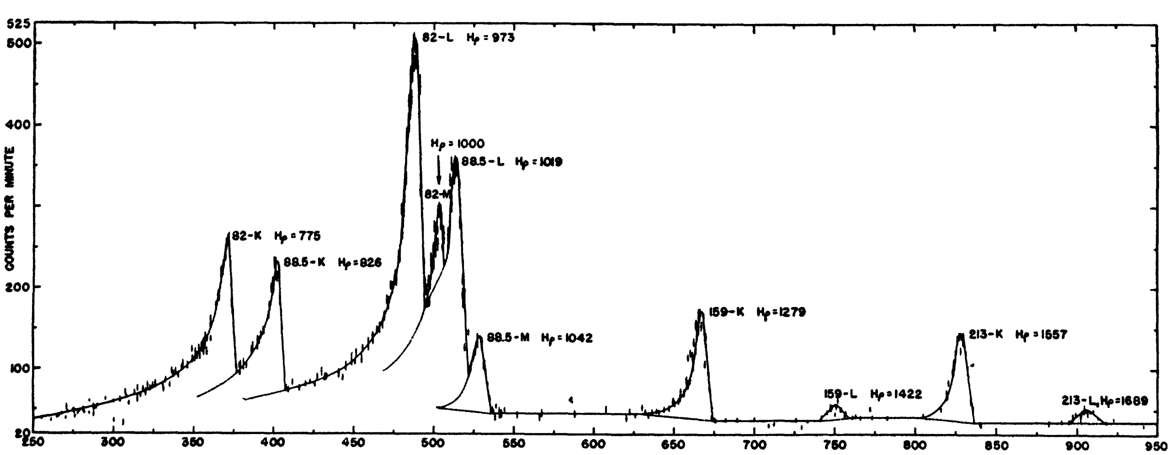

FIG. 3. Conversion electron spectra of Te^{121} and Te^{123}.

[8] J. L. Lawson and A. W. Tyler, Rev. Sci. Inst. **11**, 17 (1940).
[9] J. L. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).

TABLE II. Comparison of experimental and theoretical results.

Isomer	Transition energy (kev)	Lifetime (sec.) Experimental $\times(1+N_e/N_\gamma)$	Theoretical†	N_K/N_L Experimental	N_K/N_L Theoretical	N_K/N_γ Experimental	N_K/N_γ Theoretical
Te^{121}	82	1.0×10^{10}	5.6×10^{11} ($l=5$)	0.75 ± 0.10	2.85, 2^4 mag.* 0.06, 2^5 el.*		375, 2^4 mag.* 470, 2^5 el.*
	213		1.1×10^{-9} ($l=2$)	7.3 ± 0.3	11.8, 2^1 mag.** 7.11, 2^2 el.*	0.085 ± 0.035	0.084, 2^1 mag.*** 0.097, 2^2 el.***
Te^{123}	88.5	0.6×10^{10}	2.4×10^{11} ($l=5$)	0.68 ± 0.10	3.3, 2^4 mag.* 0.1, 2^5 el.*		300, 2^4 mag.* 375, 2^5 el.*
	159		5.1×10^{-9} ($l=2$)	8.9 ± 0.8	11.9, 2^1 mag.** 6.1, 2^2 el.*	0.18 ± 0.08	0.175, 2^1 mag.*** 0.27, 2^2 el.***
Sb^{121}	610		7.0×10^{-12} ($l=2$)			0.004 ± 0.002	0.004, 2^2 el.***

† Theoretical lifetimes have been calculated from the formula used by Axel and Dancoff, Phys. Rev. **75**, 1297 (1949).
* Theoretical values of N_K/N_L have been obtained from the analyses of Hebb and Nelson (see reference 11) and Drell (see reference 12).
** Theoretical values of N_K/N_L have been obtained from curves of Lowen and Tralli (see reference 13).
*** Theoretical values of N_K/N_γ have been obtained from the tables computed by Rose and others (see reference 10).

ations. Theoretical values here used are the accurate numerical values obtained by Rose and others.[10] For the N_K/N_L ratios of the same transitions, however, the experimental values lie between those for 2^1 magnetic and 2^2 electric. S. Frankel, of this Department, has been unable to confirm the existence of the previously[4] reported delayed transition in a source of type (a). He used scintillation counters, which should be more reliable in this lifetime region than Geiger-Müller counters, and finds an upper limit of 2×10^{-8} sec. for the half-lives of the 213 and 159 kev excited states.*

Theoretical values used for analysis here were obtained from the approximate analytical expressions derived by Hebb and Nelson[11] and by Drell,[12] and also from the curves of Lowen and Tralli.[13] No assignments of the proportions of magnetic to electric radiations will be made from these values as it appears probable that both theory and experiment are not sufficiently accurate at this stage. The decay schemes proposed for the Te^{121} and Te^{123} isomers are shown in Fig. 4.

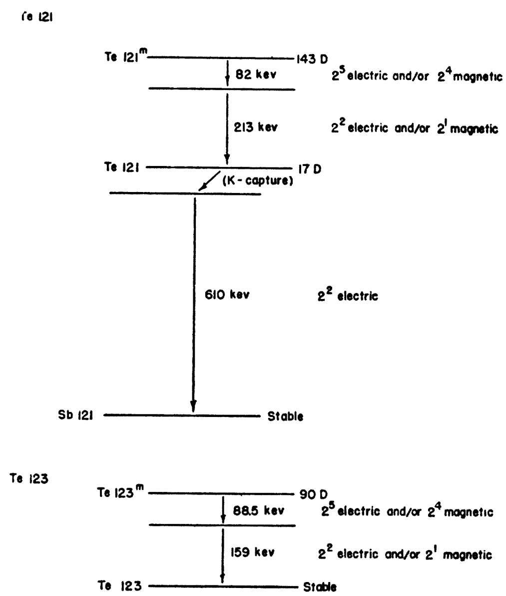

FIG. 4. Proposed decay schemes of Te^{121} and Te^{123} isomers.

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[10] M. E. Rose *et al.*, "Tables of *K*-shell conversion coefficients" (privately distributed).

* *Note added in proof:* See also M. Deutsch and W. E. Wright, Phys. Rev. **77**, 139 (1950).

[11] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940).

[12] S. D. Drell, Phys. Rev. **75**, 132 (1949); S. D. Drell, Ph.D. thesis, University of Illinois (1949).

[13] I. S. Lowen and N. Tralli, Phys. Rev. **75**, 529 (1949).