Radioactive Te from Sb Bombardment

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A radioactive isomer has been found in Te^{121} with the help of a curved crystal x-ray spectrograph. The pair consists of a new 17 ± 1-day activity produced by the reactions Sb $(d, 2n)$ and Sb (p, n) and a previously assigned activity evaluated here as 143 ± 5 days. Sb and Te x-rays, a 0.61-Mev gamma-ray, a 0.223-Mev gamma-ray, and conversion electrons are associated with the long period. Sb x-rays and a 0.61-Mev gamma-ray are associated with the short period. The observations are simply explained by the isomeric transition. No evidence of the "fast" gamma-transition was found.

INTRODUCTION

TWO activities have been found in the Te chemical fraction after deuteron bombardment of antimony. An activity of half-life 30 days consisting of several gamma-ray energies was reported,[1] two of which, 0.082 Mev and 0.0882 Mev, are internally converted with K-L-M conversion electron energy differences characteristic of Te. Other gamma-ray energies of 0.136, 0.1573, 0.2108, and 0.615 Mev were also found[1] in the Te fraction. A 125-day Te activity has been produced by the reactions[2] Sb $(d, 2n)$, Sb (p, n), and Sn (α, n) and has been assigned to Te^{121}. There is evidence of shorter half-lives in the activity resulting from the Sn (α, n) reaction.[2]

The radiations from the long period Te^{121} are very complex consisting of x-rays, internal conversion electrons, and gamma-rays. Two gamma-ray energies, 0.23 Mev and 0.61 Mev, are associated with this activity.[1,3] The 0.23-Mev gamma-ray is strongly internally converted[3,4] and there is some evidence that the 0.61-Mev gamma-ray is partially internally converted.[4] X-rays characteristic of Sb and shorter wave-length "tellurium-like" x-rays were detected[5] in the Te fraction after deuteron bombardment of Sb. The two x-ray wave-lengths were distinguished by critical absorption and fluorescent measurements.[5] Coincidence counter observations[3] have shown that the "tellurium-like" x-ray is associated with the 0.23-Mev gamma-ray but chemical tests[5] for an isomeric transition in Te failed to show a daughter product. The "tellurium-like" x-ray has been interpreted[3,5,6] as caused by K-capture in Te^{121} followed immediately by internal conversion of the 0.23-Mev gamma-ray in the singly-ionized K-shell. The x-ray is then emitted by the Sb atom having both K-electrons missing. The x-ray wave-length emitted by this process would differ slightly from that of Te.

It is the purpose of this paper to report the results of a study of the radiations from Te^{121} obtained with the aid of a curved crystal spectrograph.[7]

Te^{121} DECAY CHARACTERISTICS

Hilger Sb metal lab. no. 11707 was activated by 10 Mev deuterons. The sample was dissolved with a Te carrier in *aqua regia* then evaporated to dryness. The residue was taken up by hot dilute HCl and an excess of tartaric acid. The Te metal was then precipitated from this solution with hydrazine dihydrochloride. Sb was precipitated from the filtrate by H_2S.

Figure 1 shows the decay of the Te fraction starting 40 days after bombardment. An activity of half-life 17 ± 1 days is observed in addition to the longer half-life of 143 ± 5 days. The branching ratio of the long period activity to the short period is approximately 3. The 17-day activity was also observed in the Te fraction after bombardment of Sb with 5-Mev protons. The 17-day

[1] C. V. Kent and J. M. Cork, Phys. Rev. **62**, 297 (1942).
[2] G. T. Seaborg, J. J. Livingood, and J. W. Kennedy, Phys. Rev. **57**, 363 (1940).
[3] Rosalyn S. Yalow and M. Goldhaber, Phys. Rev. **67**, 59 (1945).
[4] E. B. Hales and E. B. Jordon, Phys. Rev. **64**, 202 (1943).
[5] R. D. O'Neal and Gertrud Scharff-Goldhaber, Phys. Rev. **62**, 83 (1942).
[6] Rosalyn S. Yalow and M. Goldhaber, Phys. Rev. **66**, 36 (1944).
[7] J. E. Edwards, M. L. Pool, and F. C. Blake, Phys. Rev. **67**, 150 (1945).

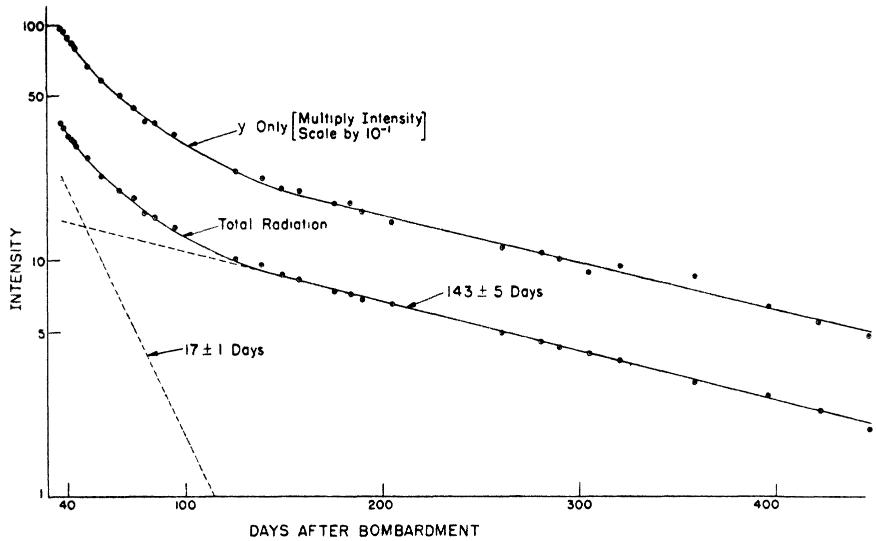


FIG. 1. Decay curve of Te^{121} from Sb+*d*.

half-life is a new activity produced by the reactions Sb (*d*, 2*n*) and Sb (*p*, *n*) and is assigned to Te^{121}. This assignment will be discussed later in the paper. The long period activity is undoubtedly the same as the 125±5-day activity assigned earlier[2] to Te^{121}. Re-evaluation of this period by the authors has yielded a half-life of 143±5 days.

The Sb fraction from Sb+*d* activation contains 2.5-day and 60-day half-lives confirming other observations.[8, 9]

Te^{121} RADIATION ENERGIES BY ABSORPTION

Aluminum absorption curves obtained in the early part of the decay while the 17-day activity was still strong showed x-rays characteristic of the Sb-Te region and conversion electrons. At the same time two gamma-ray energies, 0.61 Mev and a lower energy 0.22 Mev, were determined by lead absorption.

About 125 days after bombardment when the 17-day activity had dropped to less than $\frac{1}{10}$ the intensity of the 143-day activity additional absorption curves were obtained. These curves are shown in Figs. 2–4. Both gamma-rays of energies 0.61 Mev and 0.223 Mev are observed in the long

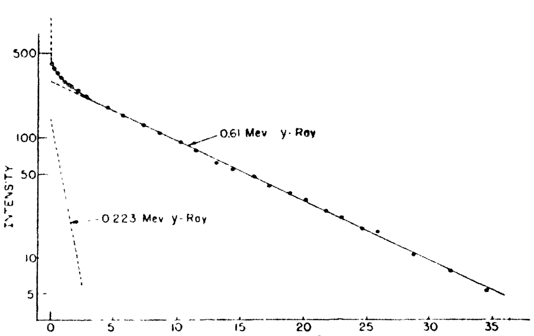


FIG. 2. Pb absorption curve of Te^{121}.

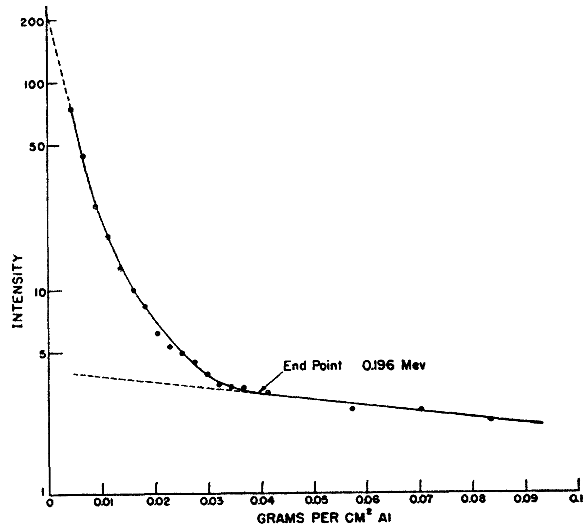


FIG. 3. Thin Al absorption curve showing conversion electrons from Te^{121}.

[8] J. J. Livingood and G. T. Seaborg, Phys. Rev. **52**, 135 (1937).
[9] J. J. Livingood and G. T. Seaborg, Phys. Rev. **55**, 414 (1939).

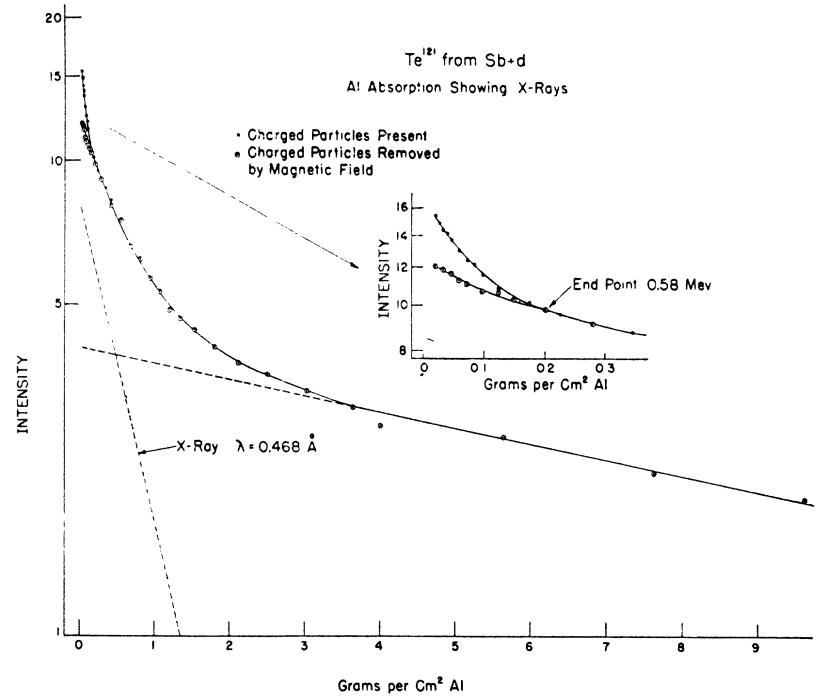


FIG. 4. Thick Al absorption curve of radiations from Te^{121}.

period activity as shown by Fig. 2. The intensity of the 0.61-Mev gamma-ray relative to the 0.223-Mev gamma-ray decreases somewhat with the decay of the 17-day activity. This indicates that the 0.61-Mev gamma-ray must be associated with both the 17-day and the 143-day activities. The aluminum absorption curve in Fig. 3 shows electrons of maximum energy 0.196 Mev indi-

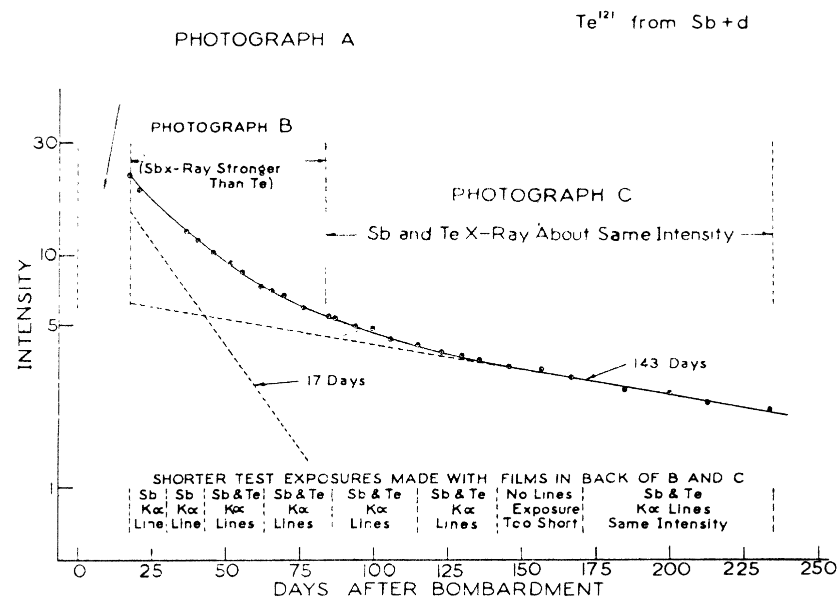


FIG. 5. Procedure of photographic analysis of x-rays from Te^{121} using a curved crystal spectrograph.

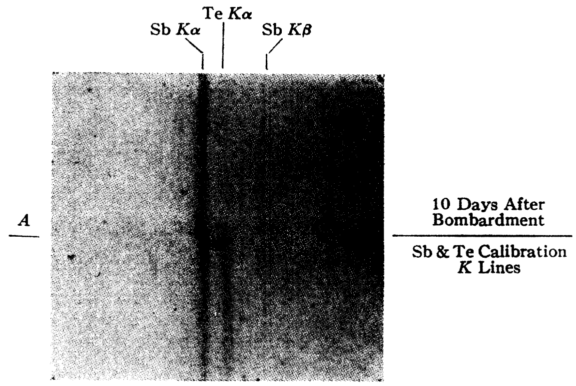
cating considerable internal conversion of the 0.223-Mev gamma-ray in the K-shell of Te or Sb. The principal curve in Fig. 4 shows aluminum absorption of the radiation after the charged particles were removed by magnetic deflection. Intensities with and without the magnetic field were obtained on the upper portion of the curve extending to the region where the readings coincided. X-rays characteristic of the Sb-Te region are shown and there is some evidence that the 0.61-Mev gamma-ray is internally converted to a slight extent.

A search for x-rays in the Sb fraction by absorption of the radiation in Al after removal of the charged particles magnetically failed to reveal any x-radiation. The possible existence of K-capture in Sb^{124} as reported[10] is not confirmed by these observations.

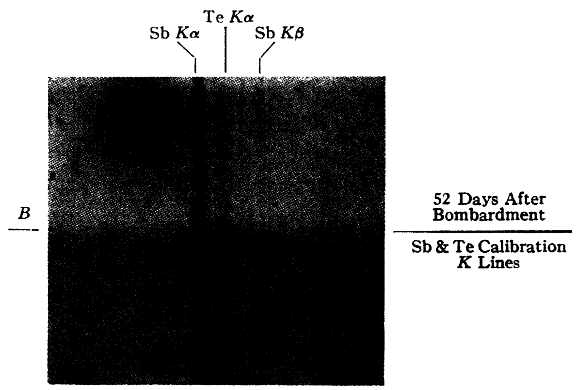
Te^{121} PHOTOGRAPHIC ANALYSIS OF X-RAYS

A curved crystal spectrograph employing a mica crystal curved to a radius of 15 inches[7] was used in photographing the x-rays emitted by Te^{121} during various phases of its decay. Figure 5 illustrates the photographic procedure. After deuteron bombardment the Sb sample was first photographed for 18 days before the chemical separation was made. The spectrograph was aligned so that $K\alpha$-radiation in the Sn, Sb, Te, I region would form lines on the film. The result of this exposure is shown in photograph A, Fig. 6. Sb $K\alpha$, Sb $K\beta$, and very weak Te $K\alpha$ lines are visible. Sb and Te calibration lines are shown in the lower half of each photograph in Fig. 6. During the exposure of photograph A, other films were placed just off the focal circle of the spectrograph in back of the main film. Each of these test films remained in position for a few days, then it was removed and replaced by a new film. In this way the progress of the main exposure could be determined and any change in the relative intensity of lines could be noted. Four such films exposed while photograph A was being made showed clearly the Sb lines, but the Te lines were not visible.

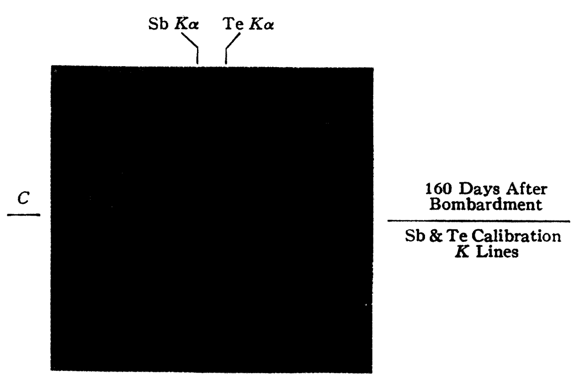
After chemical separation the Te fraction was photographed for a total of 217 days according to the procedure shown in Fig. 5. The same spectrograph was used for photographs A, B, and C. The Sb fraction was also photographed. A single exposure of the Sb fraction was made in a



A—18-day exposure of Sb sample before chemical separation (Sb x-ray much stronger than Te).



B—68-day exposure of Te fraction immediately after chemical separation.



C—149-day exposure of Te fraction following exposure B.

FIG. 6. X-ray photographs of Te^{121} taken with a curved crystal spectrograph.

[10] Allan C. G. Mitchell, Lawrence M. Langer, and Paul W. McDaniel, Phys. Rev. **57**, 1107 (1940).

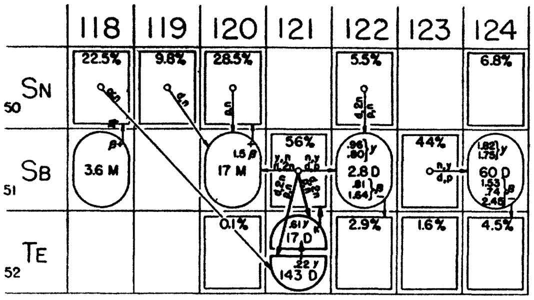


FIG. 7. Region of atomic chart showing decay process of Te^{121}.

similar spectrograph extending over a period of 120 days but no x-rays were found. Therefore, it can be assumed that the x-ray lines appearing in photograph *A* were associated with the Te fraction. The upper half of photograph *B* (Fig. 6) is the result of a 68-day exposure of the Te fraction starting immediately after chemical separation. The Sb lines are still strong but the intensity of the Te $K\alpha$ line relative to the Sb $K\alpha$ line is considerably greater than in photograph *A*. It is evident from photographs *A* and *B* that the source of Sb x-rays must be decaying more rapidly than the source of Te x-rays. The four test films obtained during the 68-day exposure also show a decrease in the intensity of Sb x-rays with respect to the Te x-rays. It may be observed from Fig. 5 that the 17-day and the 143-day activities had approximately the same average intensity during the 68-day exposure.

Photograph *C* (Fig. 6) was exposed for 149 days starting immediately after exposure *B*. The Sb and Te lines are about the same intensity and it can be seen from the decay curves of Fig. 5 that the average intensity of the 17-day activity is very small compared to the intensity of the 143-day activity during this exposure. The four test films obtained during this exposure show conclusively that Sb and Te x-rays of approximately the same intensity are associated with the 143-day activity.

DISCUSSION

The existence of a 143-day Te activity which emits x-rays characteristic of Te and Sb can be readily explained by a genetically related isomeric pair as indicated in Fig. 7. Since Sb x-rays and a 0.61-Mev gamma-ray appear to be associated with the 17-day activity as well as with the 143-day activity, these two activities logically form the isomeric pair. The highly converted 0.223-Mev gamma-ray is emitted in the isomeric transition accounting for the relatively high intensity of the Te x-rays. The 0.61-Mev gamma-ray being associated with both periods must be emitted with the return of the Sb* nucleus to the ground state following *K*-capture.

No evidence of the "fast" gamma-transition type of decay was found. If such "fast" transitions occur in the Te-Sb decay their number must be small compared to the isomeric transitions since no satellite x-ray lines were observed near the strong characteristic $K\alpha$ lines.

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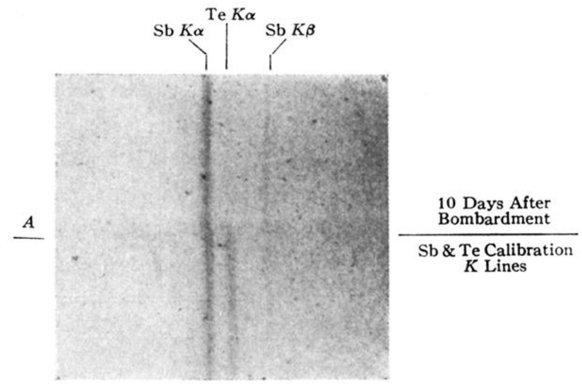
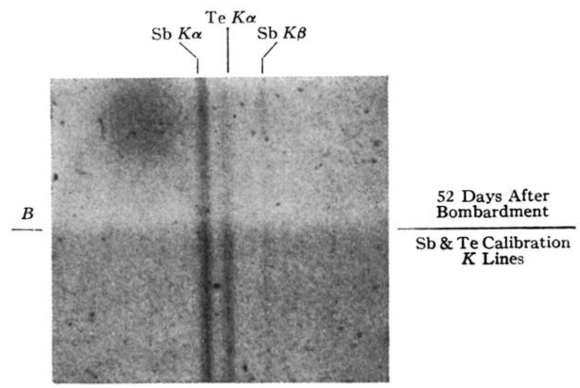
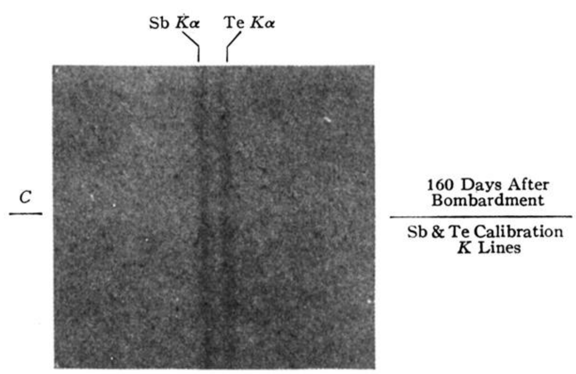


A—18-day exposure of Sb sample before chemical separation (Sb x-ray much stronger than Te).



B—68-day exposure of Te fraction immediately after chemical separation.



C—149-day exposure of Te fraction following exposure *B*.

FIG. 6. X-ray photographs of Te^{121} taken with a curved crystal spectrograph.