Radiations From Tantalum (182), Antimony (122), and Indium (116)*

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The 100-day activity was induced in tantalum irradiated by slow neutrons in the Clinton pile. The beta-rays of this isotope were found to have a range in aluminum of 0.112 g/cm², and the gamma-rays a maximum energy of 1.16±0.1 Mev as determined by coincidence absorption. The beta-gamma coincidence rate was 0.93×10^{-3} coincidence per beta-ray, independent of the beta-ray energy, and a gamma-gamma coincidence rate of $(0.27\pm0.03)\times10^{-3}$ coincidence per gamma-ray was obtained. These data indicate that beta-emission by Ta^{182} leads to an exited state of W^{182} and that de-excitation occurs with the emission of two or more gamma-rays in cascade.

The 2.8-day activity of antimony (122) was also prepared in the pile. The beta-gamma coincidence rate was found to drop to zero at 0.487 g/cm² in aluminum, corresponding to 1.19 Mev. The maximum energy of the beta-rays was measured to be 1.77 Mev.

The beta-gamma coincidence rate of the 54-minute isomer of indium (116) was found to be 1.3×10^{-3} coincidence per beta-ray independent of the beta-ray energy, and a gamma-gamma coincidence rate of $(0.9\pm0.1)\times10^{-3}$ coincidence per gamma-ray was also observed.

A disintegration scheme is given for Sb^{122}.

1. INTRODUCTION

THE radiations of tantalum (182), antimony (122), and indium (116) have been investigated by absorption and coincidence methods. An attempt has been made to correlate the coincidence rates with spectrometric results when such data are available.

The procedure for measuring beta-ray energies was the standard one of placing aluminum foils before a single counter and observing the counting rate as a function of absorber thickness. The maximum energy of the gamma-rays emitted by Ta^{182} was measured by coincidence absorption. The radioactive source was placed behind an aluminum block which served as a radiator of Compton recoils. The recoils passed through two thin-walled counters in coincidence. Aluminum absorbers were placed between the two counters, and the coincidence rate was plotted as a function of the absorber thickness. The quantum energy was taken from the end-point.

For measurement of coincidences between the beta-rays and gamma-rays emitted by each isotope, a radioactive source of low surface density was placed between two counters. Aluminum

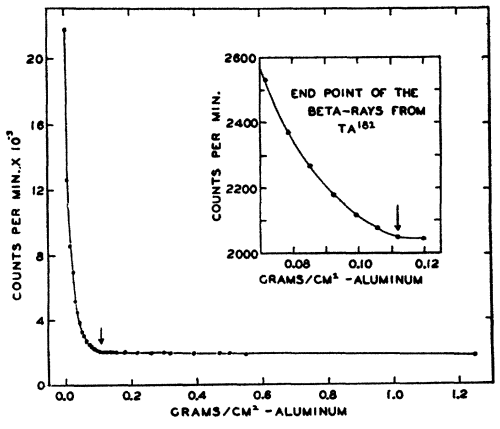

FIG. 1. Absorption in aluminum of the beta-rays of tantalum (182).

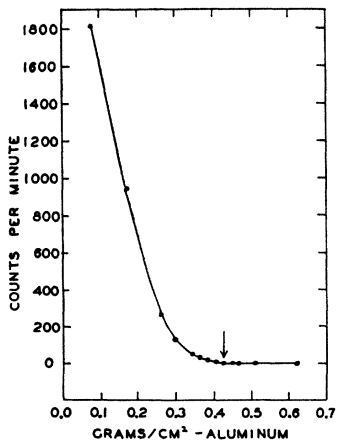

FIG. 2. Coincidence absorption of the secondary electrons of the gamma-rays from tantalum (182).

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blocks of sufficient thickness to stop the primary beta-rays were placed before each counter when the gamma-gamma coincidence rate was measured. For the measurement of beta-gamma coincidences, thin aluminum foils were placed before the beta-ray counter, and the coincidence rate was determined as a function of the aluminum thickness. The accidental coincidence rate was determined by the equation

$$A = N_1 N_2 (K\tau),$$

where $K\tau$ was two microseconds. Other details of the coincidence arrangement have been previously described.[1]

2. TANTALUM (182)

When tantalum is irradiated by slow neutrons, radioactive tantalum (182), having a half-period of about 100 days,[2] is formed. The radiations of this isotope have been investigated by a number of workers.[2–5] TaO_2 was irradiated by slow neutrons in the pile, and a chemical separation was performed. The absorption curve for the beta-rays of this isotope is given in Fig. 1. The absorption limit is seen to be 0.112 g/cm^2 in aluminum, corresponding to an energy of about 0.36 Mev calculated from the range-energy relation for homogeneous beta-rays. No beta-rays of higher energy were observed.[3]

The data for coincidence absorption of the gamma-rays from Ta^{182} are given in Fig. 2. The end point, 0.425 g/cm^2, corresponds to a quantum energy of 1.16±0.1 Mev. The coincidence absorption method measures accurately only the maximum energy of the gamma-rays. Quantum energies of 0.15, 0.22, 1.13, and 1.22 Mev have been reported as measured by a thin magnetic lens spectrometer.[4] More recently, the gamma-rays of low energy have been resolved into about sixteen lines by Cork.[5]

The beta-gamma coincidence rate of Ta^{182} is given in Fig. 3 where it is seen to be 0.93×10^{-3} coincidence per beta-ray recorded in the beta-ray counter, independent of the beta-ray energy.

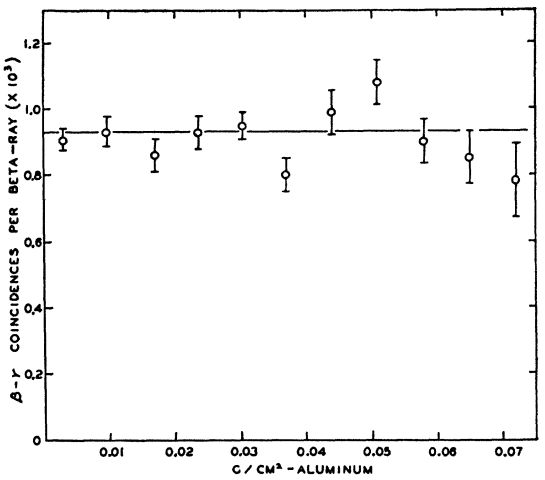

FIG. 3. The genuine beta-gamma coincidence rate of tantalum (182).

This would suggest that only one beta-ray spectrum is present. A gamma-gamma coincidence rate of $(0.27\pm0.03)\times10^{-3}$ coincidence per gamma-ray recorded in the gamma-ray counter was also observed. From these coincidence rates, it may be concluded that the beta-transition in Ta^{182} leads to an excited state of the W^{182} residual nucleus. The gamma-rays of energy 1.13 and 1.22 Mev have been reported to be of comparable intensity.[4] However, using the same counters and geometry, the coincidence rates for Sc^{46} were found to be 1.4×10^{-3} beta-gamma coincidence per beta-ray and 0.62×10^{-3} gamma-gamma coincidence per gamma-ray.[1] Since scandium (46) is known to disintegrate with the emission of a beta-ray of energy 0.36 Mev followed by gamma-rays of energy 0.90 and 1.12 Mev in cascade,[6] it seems improbable that the two gamma-rays of high energy from Ta^{182} are in cascade.

The beta-ray energy of 0.53 Mev obtained by the thin lens[4] should be regarded as more reliable than the value reported in this paper which was calculated from the absorption limit.

3. ANTIMONY (122)

Sb^{122} was prepared when metallic antimony was irradiated by neutrons in the pile. The exposure time was only 2 hours, so that the 60-day period was present with only a small intensity.

[1] C. E. Mandeville and M. V. Scherb, Phys. Rev. **73**, 141 (1948).
[2] O. Oldenburg, Phys. Rev. **53**, 35 (1938).
[3] R. V. Zumstein, J. D. Kurbatov, and M. L. Pool, Phys. Rev. **63**, 59 (1943).
[4] W. Rall and R. G. Wilkinson, Phys. Rev. **71**, 321 (1947).
[5] J. M. Cork, Phys. Rev. **72**, 581 (1947).
[6] A. E. Miller and M. Deutsch, Phys. Rev. **72**, 527 (1947).

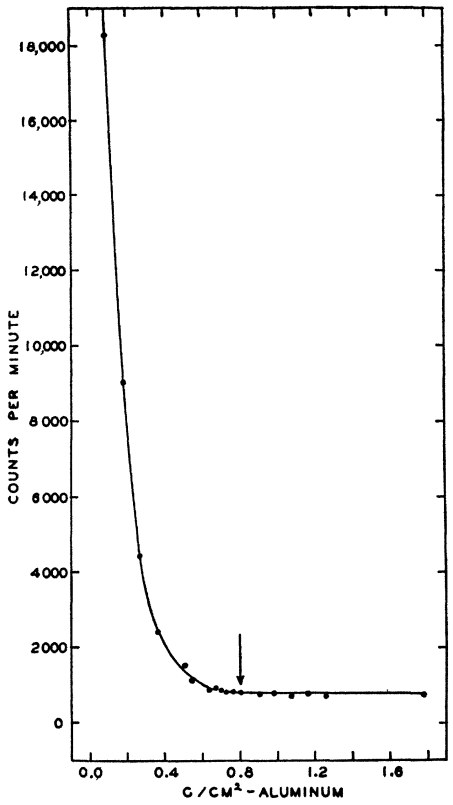

FIG. 4. Absorption in aluminum of the beta-rays of antimony (122).

Measurements were begun about 20 hours after removal of the isotope from the pile. The beta-rays of Sb^{122} have been measured previously by the absorption method by Amaki and Sugimoto,[7] who found a maximum energy of 1.64 Mev and by Mitchell, Langer, and McDaniel,[8] who report an absorption limit corresponding to 1.76±0.10 Mev.

The data obtained for absorption in aluminum of the beta-rays of Sb^{122} in the present experiment, are given in Fig. 4, where the absorption limit occurs at 0.806 g/cm² corresponding to an energy of 1.77±0.10 Mev as calculated by Feather's equation.[9] A source of radioactive material was placed in the standard position between two thin-walled Geiger counters. The beta-gamma coincidence rate plotted in Fig. 5, was observed to decrease from 0.19×10^{-3} coincidence per beta-ray recorded in the beta-ray counter at zero absorber thickness to zero at 0.487 g/cm² in aluminum, corresponding to an energy of 1.19±0.05 Mev. These data indicate that two beta-ray spectra are present having end points which differ by 0.58±0.11 Mev. Since a gamma-ray energy of 0.57 Mev has been previously reported,[4] the disintegration scheme of Fig. 6 may now be drawn for Sb^{122}. These results disagree somewhat with earlier coincidence experiments[8] which indicated an end point at 0.81 Mev for the beta-spectrum of lower energy.

Miller and Curtiss[10] have reported beta-ray energies of 1.36 and 1.94 Mev as determined by a thin magnetic lens spectrometer. These values differ in absolute value from those reported by the writers, but the energy difference is the same.

4. INDIUM (116)

The 54-minute activity was induced in a strip of indium metal (thickness 0.018 cm), irradiated by slow neutrons from a radium-beryllium source of strength 600 Mc. The genuine beta-gamma

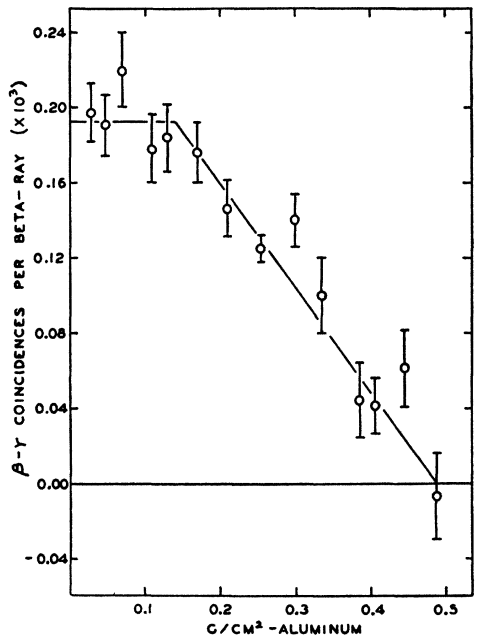

FIG. 5. Beta-gamma coincidence rate of antimony (122) as a function of the surface density of aluminum placed before the beta-ray counter.

[7] T. Amaki and A. Sugimoto, Inst. Phys. and Chem. Research, Tokyo, paper No. 853, 1650 (1938).
[8] A. C. G. Mitchell, L. M. Langer, and P. W. McDaniel, Phys. Rev. **57**, 1107 (1940).
[9] N. Feather, Proc. Camb. Phil. Soc. **34**, 599 (1938).
[10] L. C. Miller and L. F. Curtiss, Phys. Rev. **70**, 982 (1946).

coincidence rate for indium (116) is plotted in Fig. 7, where it is seen to be independent of the beta-ray energy. From the figure it is clear that no genuine coincidences exist beyond about 0.22 g/cm² of aluminum, 0.7 Mev by Feather's equation. These data are in agreement with the findings of Langer, Mitchell, and McDaniel,[11] who found genuine coincidence as far out as 1.2 Mev but seem to have correctly dismissed those above 0.8 Mev as arising from a Compton-recoil gamma-effect growing out of their geometry.

The coincidence measurements of this investigation agree reasonably well with the spectrometric findings of Lawson and Cork[12] who report an upper limit of 0.85±0.1 Mev for the beta-rays of indium (116).

The effect of the decay of the short-lived indium upon all other corrections was taken into account.[13]

5. ACKNOWLEDGMENTS

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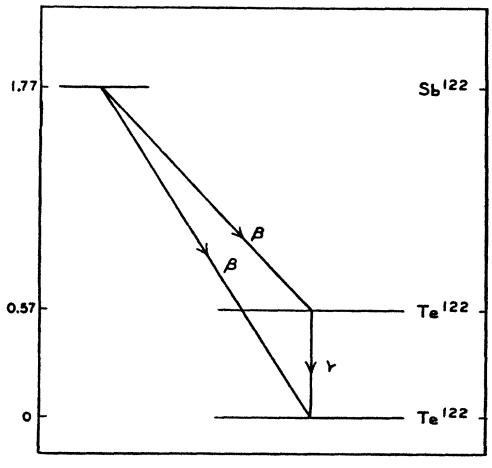

FIG. 6. Disintegration scheme of Sb^{122}.

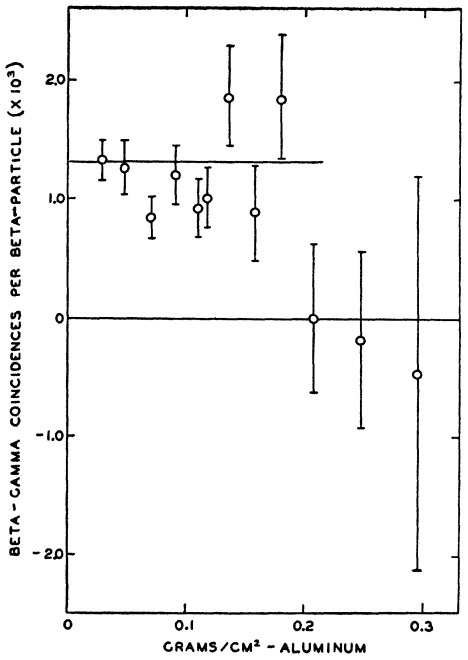

FIG. 7. Beta-gamma coincidence rate for indium (116).

6. APPENDIX: CHEMICAL PROCEDURE FOR TANTALUM

A 27-mg sample of active tantalum oxide was mixed with 150 mg of inactive Ta_2O_5 and 140 mg of inactive ZrO_2, the latter to serve as a carrier for hafnium. The mixture was fused with potassium bisulfate until clear. The fused mass dissolved completely in hot saturated ammonium oxalate solution, and from this solution the yellow tantalum-tannin complex was precipitated by tannic acid. The precautions usually taken in analysis of tantalum compounds were observed (Hillebrand and Lundell, *Applied Inorganic Analysis*, pp. 474–5). The fusion and precipitation were repeated, and the precipitate ignited to Ta_2O_5.

This partly purified Ta_2O_5 was now fused with potassium carbonate, and the melt was dissolved in aqueous potassium hydroxide. Sodium tantalate was precipitated by the addition of solid sodium chloride and the precipitate collected and washed. The sodium tantalate was converted to Ta_2O_5 by acidifying its aqueous suspension with HCl and boiling. After washing the precipitate with diluted ammonium nitrate it was collected by filtration and ignited.

The purification process was intended to separate hafnium, zirconium, tungsten, iron, calcium, potassium, and phosphorus from Ta_2O_5.

[11] L. M. Langer, A. C. G. Mitchell, and P. W. McDaniel, Phys. Rev. **56**, 380 (1939).
[12] J. L. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).
[13] L. M. Langer, A. C. G. Mitchell, and P. W. McDaniel, Phys. Rev. **56**, 422 (1939).