Coincidence and Absorption Investigation of the Disintegration of Rh^{106}, Sb^{125}, and Pr^{142}

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The disintegration of Rh^{106}, Sb^{125}, and Pr^{142} has been studied with the help of conventional absorption and coincidence counting techniques. All three isotopes exhibit complex beta-ray spectra, on the basis of the shapes of their beta-gamma-coincidence plots. A definite gamma-gamma-coincidence rate indicates cascaded gamma-rays in all the disintegration schemes. Corrections for coincidences between gamma-rays and x-rays resulting from internal conversion are discussed for the case of Sb^{125}.

THE coincidence experiments performed in this laboratory principally in conjunction with spectrographic measurements have been continued, as a possible aid in determining disintegration schemes for the active isotopes rhodium 106, antimony 125, and praseodymium 142. The general techniques employed here follow closely those used in previous work and will not be discussed in detail.[1] The counters and associated counting circuits have previously been described.[2] A constant resolving time of 2.0 microseconds was used to obtain the results to be given. The sources used for the investigation were obtained from the Oak Ridge National Laboratory.

1. RHODIUM 106

The 30-sec. Rh^{106} activity grows from 1-yr. Ru^{106}, which emits a single beta-ray group with a maximum energy of approximately 30 kev.[3] W. C. Peacock[4] has measured the energies of the beta- and gamma-rays associated with the decay of Rh^{106} with a magnetic lens spectrograph, and finds two beta-ray groups with maximum energies of 3.55 Mev (82 percent) and 2.30 Mev (18 percent); he finds three gamma-ray lines, of 0.51 Mev, 0.73 Mev, and 1.25 Mev. These measurements, combined with some coincidence experiments, led Peacock to propose the disintegration scheme shown in Fig. 1.

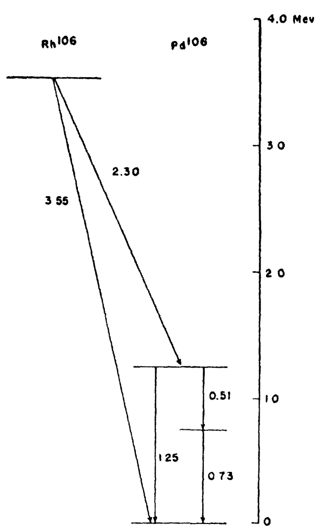

FIG. 1. Disintegration scheme for Rh^{106} as proposed by Peacock (see reference 4).

In the experiments to be described here, a beta-ray absorption curve, taken with aluminum absorbers, and analyzed by the method of Bleuler and Zünti,[5] yielded a maximum energy of 3.50 Mev, with indications of a lower energy group. The energy of the hardest gamma-ray was determined by the coincidence absorption of the Compton recoil electrons produced in an aluminum radiator and was found to be 1.3 Mev. To observe gamma-gamma- and beta-gamma-coincidences, the source was situated between a lead-cathode gamma-ray counter and an end-window beta-ray counter with a 6-mg/cm² mica window. A 1.8-g/cm² aluminum absorber placed before the beta-ray counter served to exclude beta-rays and to provide a radiator for producing secondary electrons when gamma-gamma-coincidences were investigated.

The gamma-gamma-coincidence rate per gamma-ray recorded by the lead counter was $(0.15\pm0.049)\times10^{-3}$, which indicates that at least a pair of gamma-rays is

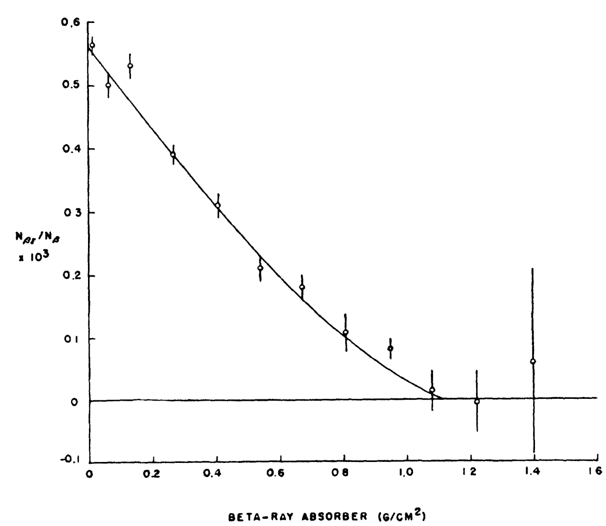

FIG. 2. Beta-gamma-coincidences from the disintegration of Rh^{106}.

[1] For a more complete discussion on coincidence counting procedure, see A. C. G. Mitchell, Rev. Mod. Phys. **20**, 296 (1948).
[2] E. T. Jurney and A. C. G. Mitchell, Phys. Rev. **73**, 1153 (1948).
[3] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).
[4] W. C. Peacock, Phys. Rev. **72**, 1049 (1948).
[5] E. Bleuler and W. Zünti, Helv. Phys. Acta **19**, 375 (1946).

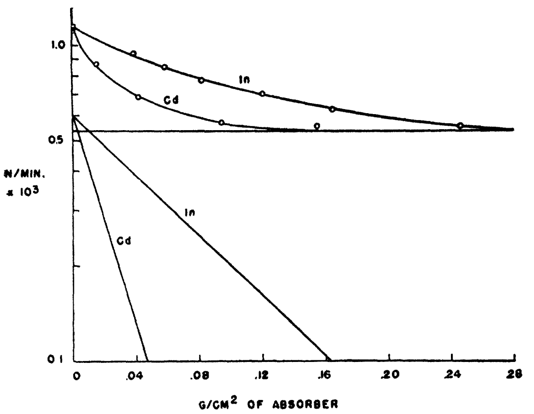

FIG. 3. Critical absorption of characteristic tellurium x-rays in the beta-ray absorption curve for Sb^{125}.

emitted in cascade in some of the disintegrations. The gamma-ray counting efficiency for the beta-ray counter combined with an aluminum radiator is not known, however, and no further information can be inferred from the gamma-gamma-coincidence rate. The beta-gamma-coincidence rate per recorded beta-ray as a function of beta-ray absorber is given in Fig. 2; the curve shows clear evidence of a complex beta-ray spectrum, with a low energy group whose maximum energy is around 2.3 Mev. Above 2.3 Mev no beta-gamma-coincidences are observed, from which fact one concludes that the higher energy group of beta-rays leads directly to the ground state of Pd^{106}. The results presented here are in good agreement with Peacock's proposed disintegration scheme.

2. ANTIMONY 125

Kern, Mitchell, and Zaffarano,[6] using a magnetic lens spectrometer, have found the following beta- and gamma-ray energies associated with the disintegration of Sb^{125}: Beta-ray groups with end-point energies of 0.621 Mev, 0.288 Mev; gamma-ray lines of 0.646 Mev, 0.609 Mev, 0.431 Mev (*I.C.*), 0.174 Mev (*I.C.*), 0.125 Mev, and 0.110 Mev (*I.C.*), in which the symbol (*I.C.*) denotes internal conversion. Friedlander, Goldhaber, and Scharff-Goldhaber[7] report further that a metastable level of approximately two months half-life exists in Te^{125}, and their absorption measurements on the conversion electrons from the delayed gamma-radiation indicate a quantum energy of 120 kev. Kern *et al.*[6] find that the 110-kev line mentioned is delayed.

The absorption and coincidence experiments to be described here are for two cases: (1) with a source which contains the two-month tellurium gamma-ray activity, and (2) with a source which has had chemical separation from tellurium. Identical counter geometries were used in both cases.

In the experiments with the first source, an aluminum absorption curve of the beta-rays appeared to have an end point at approximately 0.7 Mev, with considerable "tailing off" for absorber thicknesses out to about one centimeter. The activity in the "tail" proved to be characteristic K x-radiation from tellurium, following internal conversion of gamma-rays, as shown by the critical absorption curves of Fig. 3. These curves were taken with enough aluminum to stop beta-rays of energies less than 0.300 Mev. The customary beta-gamma-coincidence plot displayed the saddle shape shown in Fig. 4. It seemed likely that a considerable number of coincidences between gamma-rays and x-rays, following internal conversion, were being recorded (at a rate to be symbolized by "$N_{x\gamma}$").

The ratio $N_{x\gamma}/N_x$ should be independent of the absorber thickness placed before the beta-ray counter, which in the present experiments was the only counter capable of recording x-rays. By extrapolation of the x-ray fraction in the total absorption curve, it was possible to arrive at a value for N_x for any absorber thickness. With an absorber made up of 0.270 g/cm² of aluminum and 0.112 g/cm² of lead, it was possible to exclude all the beta-rays and nearly all the x-rays from the beta-counter and thus to arrive at nearly the true value for the ratio $N_{\gamma\gamma}/N_\gamma$, which was found to be $(0.033\pm0.016)\times10^{-3}$. Then, by using enough aluminum absorber to remove the beta-rays, a value for $(N_{x\gamma}+N_{\gamma\gamma})/(N_x+N_\gamma)$ was found, from which, by subtraction, the value of $N_{x\gamma}/N_x$ was secured. It was possible, then, to arrive at the proper value of $N_{\beta\gamma}$ for each absorber thickness by subtracting the $N_{x\gamma}$ rate in addition to the usual chance, cosmic-ray, and gamma-gamma-rates which are subtracted from the total coincidence rate. The true plot of $N_{\beta\gamma}/N_\beta$, as a function of beta-ray absorber thickness, is reproduced in Fig. 5. Because of the fact that many component rates add to give the total coincidence rate, the errors in counting the true beta-gamma-coincidence rate become large.

From Fig. 5 it is apparent that the highest energy group of beta-rays is not emitted in coincidence with a gamma-ray; thus, the transitions associated with that

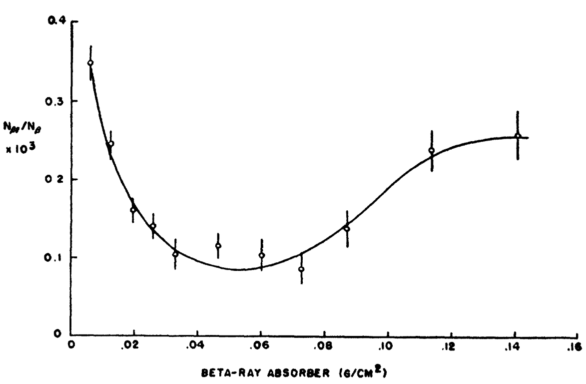

FIG. 4. Beta-gamma-coincidences from the disintegration of Sb^{125}, uncorrected for x-ray-gamma-coincidences.

[6] B. D. Kern, A. C. G. Mitchell, and D. J. Zaffarano, Phys. Rev. **76**, 94 (1949).
[7] Friedlander, Goldhaber, and Scharff-Goldhaber, Phys. Rev. **74**, 981 (1948).

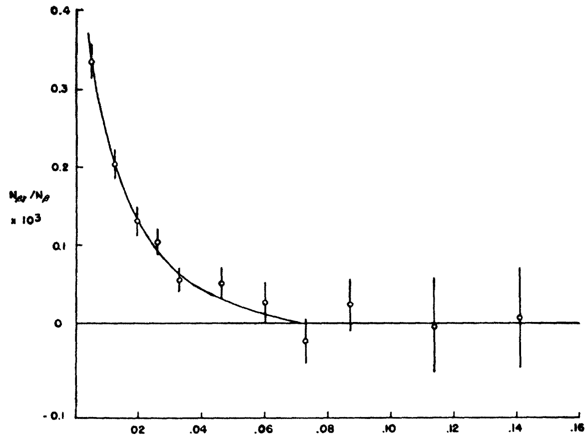

FIG. 5. Beta-gamma-coincidences from the disintegration of Sb^{125}, corrected for x-ray-gamma-coincidences.

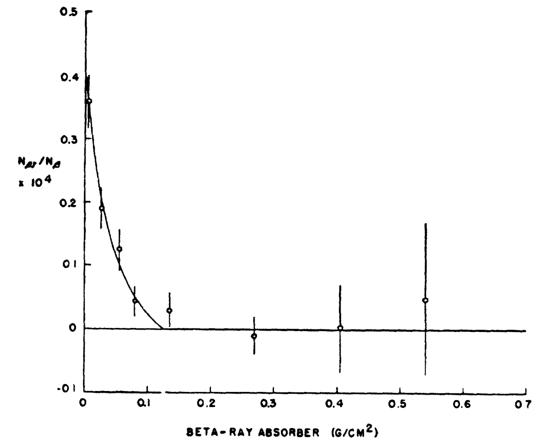

FIG. 6. Beta-gamma-coincidences from the disintegration of Pr^{142}.

group lead either to the ground state of Te^{125} or directly to the known metastable level in Te^{125}. The end point of the highest energy electron group which is in coincidence with a gamma-ray is around 0.25 Mev, within rather large limits of error. Also, the curve gives no indication of coincidences between conversion electrons from the strong 0.436-Mev gamma-ray line reported by Kern *et al.*[6] and other gamma-rays.

Essentially the same results were obtained from similar experiments done with the source which had had two-month Te^{125} gamma-ray activity chemically removed. The low energy beta-ray group end point appeared at 0.24 Mev, and the value of $N_{\beta\gamma}/N_\beta$ was again 0.34×10^{-3} for no absorber before the beta-ray counter. It was not expected that enough of the conversion electrons from the 0.110-Mev gamma-ray could be transmitted by the counter window to have material effect on the shape of the $N_{\beta\gamma}/N_\beta$ *vs.* absorber thickness plot.

3. PRASEODYMIUM 142

Mandeville[8] has reported a series of coincidence and absorption experiments on the radiations from the 19.3-hr.[9] activity of Pr^{142}. His results indicate a complex beta-ray spectrum, with end points of 2.21 Mev and 0.215 Mev, and at least two gamma-rays, the hardest of which has an energy of 1.74 Mev. He also reports gamma-gamma-coincidences and beta-gamma-coincidences which involve only the low energy group.

As a part of the present investigation, the beta-ray end-point energy was found to be 2.52 Mev by absorption in aluminum, and the energy of the hardest gamma-ray was found to be 1.53 Mev by coincidence absorption of Compton recoil electrons.

The rate of counting beta-rays was much higher than that of counting gamma-rays in the usual coincidence arrangement; apparently most of the transitions from Pr^{142} lead directly to the ground state of Nd^{142}. In this same arrangement, the gamma-gamma-coincidence rate was nearly zero, partly because of the low sensitivity of the beta-ray counter for counting gamma-rays. With the source placed between two counters which have lead cathodes, the gamma-gamma-coincidence rate was found to be $(0.10\pm 0.075)\times 10^{-3}$ per counted gamma-ray. The fraction of 1.53-Mev gamma-rays counted is known to be around 1.2×10^{-3} for the geometry employed; it is not reasonable to suppose the 1.53-Mev gamma-ray to be simply in cascade with a single lower energy gamma-ray, then, for the counter sensitivity for a gamma-ray of the difference energy (approximately 0.7 Mev) is about 0.7×10^{-3}, and for the cascaded pair, one would expect a gamma-gamma-coincidence rate of

$$\frac{N_{\gamma\gamma}}{N_\gamma}=\frac{2\omega^2\epsilon_1\epsilon_2}{\omega(\epsilon_1+\epsilon_2)}=\frac{1.68\times 10^{-6}}{1.9\times 10^{-3}}=0.89\times 10^{-3}.$$

Here $\omega\epsilon_1$ is the fraction of the 1.53-Mev gamma-rays counted, and $\omega\epsilon_2$ is the fraction of the 0.7-Mev gamma-rays counted.

The plot of $N_{\beta\gamma}/N_\beta$ as a function of beta-ray absorber thickness is given in Fig. 6. As was expected, no evidence of coincidence is found between the 2.52-Mev beta-ray group and gamma-rays. A second beta-ray group appears, however, with an end-point energy around 0.35 Mev.

The results, except for some lack of agreement in the energy determinations, agree with Mandeville's findings. It is believed that a careful spectrographic analysis, especially of the gamma-ray spectrum, will have to be made before a complete disintegration scheme can be constructed.

ACKNOWLEDGMENTS

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[8] C. E. Mandeville, Phys. Rev. **75**, 1287 (1949).
[9] DeWire, Pool and Kurbatov, Phys. Rev. **61**, 564 (1942).