Disintegration of I^{124} and I^{126}

Allan C. G. Mitchell, J. Y. Mei, Fred C. Maienschein, and Charles L. Peacock
Indiana University, Bloomington, Indiana

(Received August 15, 1949)

The nuclear radiations from I^{124} (4 days) and I^{126} (13 days) have been measured. I^{124} decays to Te^{124} with the emission of three positron groups with end points at 2.20±0.01, 1.50±0.01, and 0.67±0.05 Mev, possibly accompanied by some K-electron capture. Gamma-rays of energy 0.603±0.002, 0.73±0.01, 1.72±0.02, and 1.95±0.05 are given off in the disintegration. I^{126} decays to Xe^{126} with the emission of two beta-ray groups of energies 1.268±0.010 and 0.85±0.01 Mev, together with a gamma-ray of energy 0.395±0.005 Mev. An active state of I, of 13.0±0.5 hr. half-life, which decays by K-capture and the emission of an internally converted gamma-ray of energy 0.159 Mev, has been found. This activity is assigned to I^{123}.

I. INTRODUCTION

THE nuclear radiations of I^{124} are of interest because that isotope is a positron emitter which goes to Te^{124}, and the energy levels of Te^{124} have been determined from the disintegration[1,2] of Sb^{124}. The disintegration scheme of Sb^{124} is rather complicated, giving rise to some five levels of Te^{124}, and it seems, therefore, of interest to try to confirm the level scheme from an investigation of the "pair nucleus," I^{124}. In the method of preparation of I^{124} used here, some I^{126} is also produced, and the disintegration scheme of this element has also been worked out.

About all that is given in the tables about I^{124} is that it is a positron emitter whose half-life is 4.0 days. It was originally prepared by Livingood and Seaborg[3] by bombarding antimony with high energy alpha-particles. I^{126} was also prepared by the same authors,[3] by a number of different reactions. It was found to have a half-life of 13.0 days and to emit electrons, whose maximum energy was determined by absorption as 1.1 Mev, and gamma-rays whose energy was determined as 0.5 Mev by lead absorption.

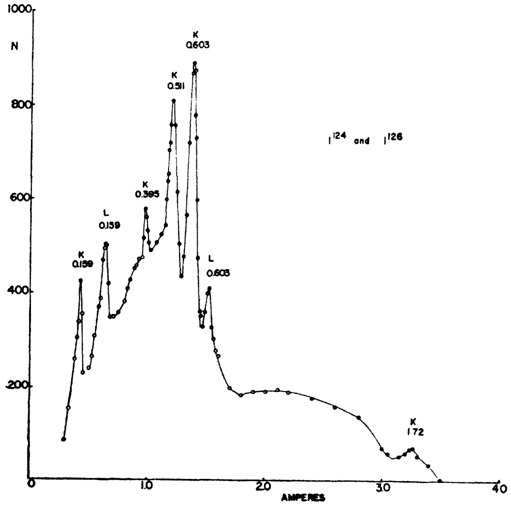

FIG. 1. Spectrum of photoelectrons ejected from lead radiator by gamma-rays of I^{124} and I^{126}.

In the present experiments, metallic antimony was bombarded by 23-Mev alpha-particles in the Indiana University cyclotron. For most of the measurements described here, bombardments of approximately 100 μa-hr. were used.

In order to separate the iodine from the target material, the (powdered) antimony was scraped off the target into a distilling flask. A small amount of a solution of KI, of known iodide concentration, was added to act as carrier. Nitric acid was then added to the mixture and a condenser was connected to the distilling flask. On boiling the mixture, iodine collected in the condenser and was washed out with carbon tetrachloride. The iodine in carbon tetrachloride was then transferred to a separatory funnel, the iodine reduced to iodide by $NaHSO_3$, and the resulting iodide ion was precipitated from the water layer as AgI.

II. APPARATUS AND RESULTS

The spectrum of the photoelectrons ejected from a radiator was measured by a magnetic lens spectrometer which has been described by Kern, Zaffarano, and Mitchell.[1,4] The Geiger-Müller counter used in these experiments was of the end window type with a window thin enough to transmit electrons of around 10 kev and above. Since the window was not supported on a grid, it was possible to measure the complete spectrum with this counter. Sources of active AgI were placed in a copper capsule thick enough to stop all beta-rays. Lead radiators of various thicknesses and one uranium radiator were used in the series of experiments.

In the first experiment, the source was placed in the spectrometer approximately 24 hours after the end of the bombardment. Figure 1 shows the distribution of photoelectrons from a lead radiator of surface density 31 mg/cm². Photoelectron peaks can be seen corresponding to the following gamma-ray lines: K and L for 0.159 Mev; K for 0.395 Mev; K for 0.511 Mev, annihilation radiation; K and L for 0.603 Mev; and a weak K line for a gamma-ray of 1.72 Mev. The photoelectron peak for annihilation radiation served as a

---

[1] Kern, Zaffarano, and Mitchell, Phys. Rev. **73**, 1142 (1948).

[2] C. S. Cook and L. M. Langer, Phys. Rev. **73**, 1149 (1948).

[3] J. J. Livingood and G. T. Seaborg, Phys. Rev. **54**, 775 (1938).

[4] Kern, Mitchell, and Zaffarano, Phys. Rev. **76**, 94 (1949).

calibration point for the spectrum. The strong line at 0.603 ± 0.002 Mev corresponds to the line at 0.603 Mev found in Sb^{124} and the line at 1.72 ± 0.02 Mev, though weak and poorly defined, corresponds to a line seen in Sb^{124} of 1.71-Mev energy.

In order to check on which lines might be due to I^{124} and which to I^{126} the same source was measured on two additional occasions each a weak apart. On the second running, about five days after the run shown in Fig. 1, it was found that the *K* and *L* lines corresponding to the gamma-ray at 0.159 Mev were entirely absent. It was shown later that this line has a half-life of 13 hours. Of the remaining lines, successive experiments showed that those due to annihilation radiation, the gamma-ray at 0.603 Mev and that at 1.72 Mev all decayed with a half-life of 4 days, while that corresponding to the gamma-ray of 0.395 Mev decayed with a half-life of 13 days.

Subsequent experiments, in which a uranium radiator was used, confirmed the existence of the line at 1.72 Mev and showed in addition a higher energy line at 1.95 ± 0.05 Mev. A careful search, using the same source, but a lead radiator, brought to light another weak line at 0.73 ± 0.01 Mev.

The line at 0.395 Mev has a half-life of 13 days and must be attributed to I^{126}. Those at 0.603, 0.73, 1.72, and 1.95 Mev are attributed to I^{124}. The lines shown by Sb^{124} and those exhibited by I^{124} are compared in Table I. The origin of the line at 0.159 Mev will be discussed below.

The measurement of the particle spectrum—electrons and positrons—was accomplished through the use of two instruments. Since the magnetic lens spectrometer was not equipped with a spiral baffle to separate positive from negative electrons, a small 180°-type spectrometer, described by Peacock and Wilkinson,[5] was used. Actually, spectra were measured in both instruments and analysis of the data showed that quite good agreement was obtained between the two.

TABLE I. Gamma-ray lines from Sb^{124} and I^{124}.

Sb^{124}	I^{124}
0.603	0.603 ± 0.002
0.651	—
0.71	0.73 ± 0.01
1.705	1.72 ± 0.02
2.06	1.95 ± 0.05

The complete spectrum of all particles as measured in the magnetic lens spectrometer is shown in Fig. 2. This spectrum, taken in its entirety with the thin window counter, stretches from approximately 10 kev to 2.2 Mev. The features of the spectrum are: an Auger line, *A*, at 21.6 kev, *K* and *L* conversion lines for the gamma-ray at 0.159 Mev, and *K* lines for the gamma-rays at 0.395 and 0.603 Mev, together with the electron and positron distribution.

Since the line at 0.159 Mev had been found, in the photoelectron investigation, to decay with a short half-life, measurements were made over this region of the spectrum for a period of several days. The intensity of the *K* and *L* lines of the 0.159-Mev gamma-ray was found to decay with a half-life of 13.0 ± 0.5 hr. Since the chemical procedure involved ensures that only iodine is used as the source material and since the activity decays with a 13-hr. period, rather than being observed to grow and eventually reach secular equilibrium with the longer-lived decay products, the 0.159-Mev line is either connected with a metastable state of iodine, or arises from the reaction $Sb(\alpha,2n)I$.

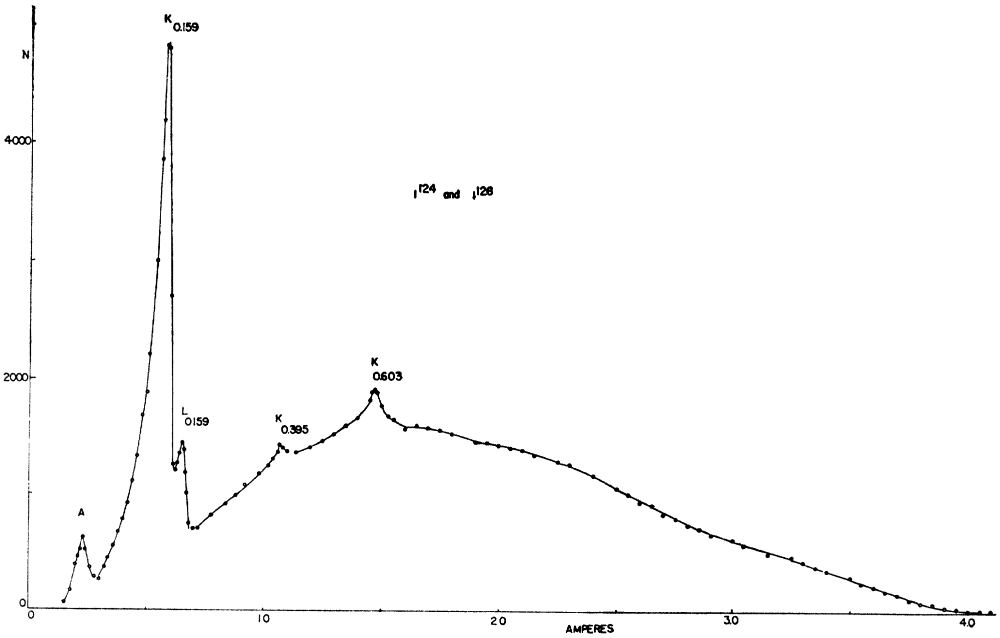

FIG. 2. Particle spectrum (electrons and positrons) of I^{124} and I^{126}.

---

[5] C. L. Peacock and R. G. Wilkinson, Phys. Rev. 74, 297 (1948).

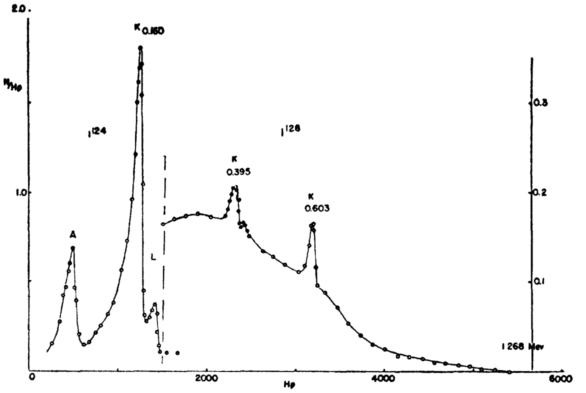

FIG. 3. Internal conversion lines from I^{124} and I^{126} superimposed on beta-ray spectrum of I^{126}.

Figure 3 shows the electron-spectrum taken on the 180° spectrometer. Figures 4 and 5 show the Fermi-plots of the electron spectrum and the positron spectrum, respectively. As in the investigation of the photoelectrons, the internal conversion line associated with the 0.603-Mev gamma-ray decays with a 4-day half-life and is due to I^{124}, while that associated with the 0.395-Mev line decays with a 13-day half-life and is due to I^{126}. In addition, the positron spectrum shows a 4-day half-life and the continuous electron spectrum, one of 13 days.

The analysis of the continuous electron distribution, I^{126}, by the method of Fermi-plots, shows that there are two groups of beta-rays; one with an end point energy of 1.268±0.01 Mev (27 percent abundance) and the other with an end point energy of 0.85±0.03 Mev (73 percent abundance). The comparative half-lives for the two groups are: $ft=2.5\times10^8$ for the high energy group; and $ft=2.7\times10^7$ for the low energy group.

The analysis of the positrons of I^{124} by the same method shows three groups of positrons. In addition, the high energy group has a "forbidden-shape." This is shown in the inset of Fig. 5, in which curve A is a plot of the data employing the usual "allowed" functions and curve B that obtained when the correction term, usually called "a" is used.[6] This type of shape is attributed to an axial vector type interaction and is *first forbidden*, with $\Delta j=\pm2$ and a change of parity. The three groups obtained by this analysis have end point energies at 2.20 ±0.01 Mev (51 percent abundance), 1.50±0.01 Mev (44 percent abundance), and 0.67±0.05 Mev (5 percent abundance). The comparative half-lives for the three groups are: 26.8×10^6, 6.8×10^6, and 1.4×10^6, respectively.

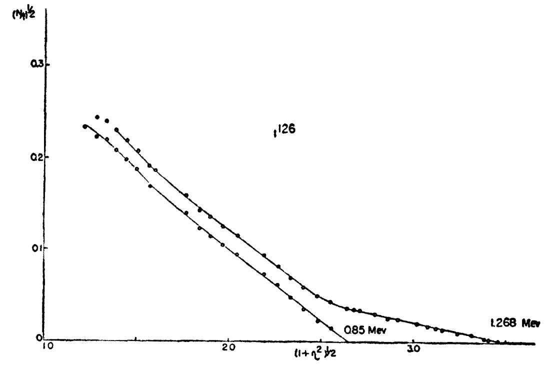

FIG. 4. Fermi-plot of electrons from I^{126}.

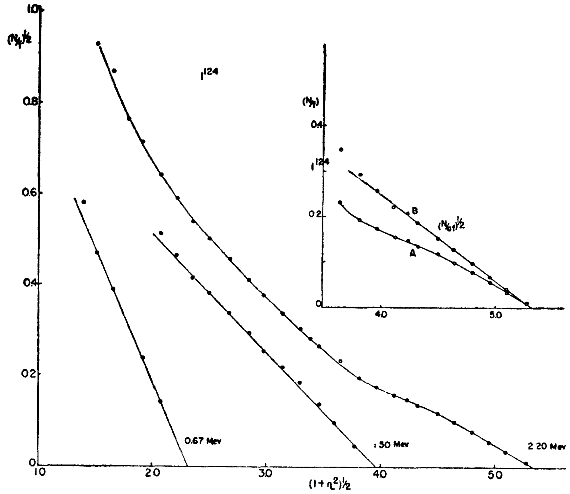

FIG. 5. Fermi-plot of positrons from I^{124}.

III. DISCUSSION OF RESULTS

(a) $I^{124}\rightarrow Te^{124}$. Half-Life 4 Days

I^{124} goes to Te^{124} with the emission of positrons, and with possibly some K electron capture. Gamma-rays of energy 0.603±0.002, 0.73±0.01, 1.72±0.02, and 1.95±0.05 Mev are observed, the strongest line being that at 0.603 Mev. In addition, three positron groups are found of energies 2.20±0.01, 1.50±0.01, and 0.67 ±0.05 Mev. The best energy and intensity fit can be obtained in the disintegration scheme if it is assumed that the highest energy positron group goes to the first excited state of Te^{124} at 0.603 Mev. The proposed disintegration scheme is shown in Fig. 6 together with

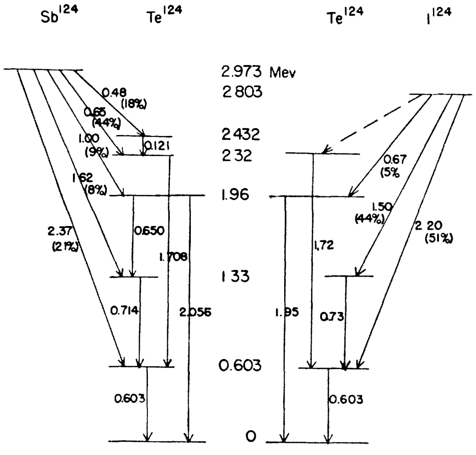

FIG. 6. Disintegration scheme of I^{124}, also showing disintegration scheme of Sb^{124}.

---

[6] E. J. Konopinski, Rev. Mod. Phys. **15**, 209 (1943). For the application of this method, see also C. L. Peacock and A. C. G. Mitchell, Phys. Rev. **75**, 1272 (1949).

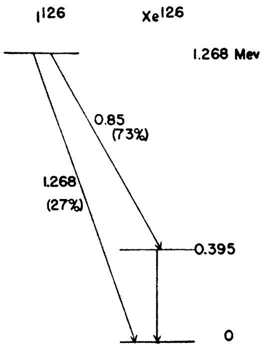

FIG. 7. Disintegration scheme of I^{126}.

that of Sb^{124}. The levels fit quite well, within the limit of the experimental errors, with those previously determined. The fit obtained for the lowest energy positron group is not good, but this group is quite weak and is determined as a result of two previous subtractions. The fact that the line at 1.72 Mev appears, where there is apparently no associated positron group, suggests that it arises as a result of K-capture.

(b) $I^{126} \rightarrow Xe^{126}$. Half-Life 13 Days

The spectrum of I^{126} consists of two beta-ray groups of energies 1.268±0.010 (27 percent) and 0.85±0.01 (73 percent) Mev together with one internally converted gamma-ray of energy 0.395±0.005 Mev. The disintegration scheme is given in Fig. 7.

(c) Remarks on the 13-Hour Activity

From the chemical procedures involved and from the fact that the line at 0.159 Mev is observed to decay with a 13-hr. half-life, rather than to grow and eventually reach secular equilibrium with one of the longer periods, it is supposed that the 0.159-Mev line arises from an isotope of *iodine*. A careful search was made for any positrons or beta-ray groups which might decay with a 13-hr. half-life but none was found. It is therefore certain that this state decays by the emission of an internally converted gamma-ray only. The question now arises as to whether this activity belongs to I^{124}, to I^{126}, or to an iodine formed from $Sb(\alpha,2n)I$. In order to get information on this point, I^{127} was bombarded with fast neutrons—$Li(d, n)$—at the cyclotron. The source was, unfortunately, not strong enough to measure in a spectograph. The period was followed with a counter. Measurements of the electrons on the one hand and the gamma-rays on the other, showed only the 25-min. period of I^{128} and the 13-day period of I^{126}. No 13-hr. component was observed. While not conclusive, this experiment suggests that the 13-hr. period is not connected with I^{126}.

A conclusive experiment, however, was performed in which the results obtained using ordinary antimony, on the one hand, and separated Sb^{123} (96.7 percent) on the other, were compared. A sample of separated Sb^{123}, weighing 100 mg, was obtained from the Stable Isotopes Division of the Oak Ridge National Laboratory. In order to make the comparison, a sample of ordinary antimony, weighing 100 mg, was given a total irradiation of 80-μa-hr. of 23-Mev alpha-particles, and a source of iodine prepared in the usual manner. The low energy part of the beta-ray spectrum from this source was investigated in the magnetic lens spectrograph. A source was prepared in the same manner from the separated Sb^{123} sample, precautions being taken to avoid, as far as possible, any contamination from ordinary antimony. The results of both measurements are shown in Fig. 8, in which curve (a) gives the results for the ordinary sample and (b) those for the separated sample. It will be seen at once that, although the separated sample had a somewhat stronger activation as judged from the intensity of the beta-ray spectrum and the internal conversion line for the 0.395-Mev gamma-ray, the internal conversion line for the 0.159-Mev gamma-ray is extremely weak in the separated sample while the peak for this line, in the normal sample, gives a counting rate of about 2000 counts/min. This activity is therefore connected with the alpha-particle bombardment of Sb^{121} and is probably to be attributed* to I^{123}.

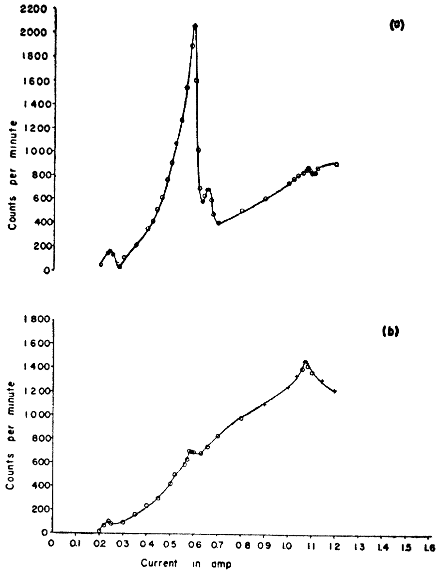

FIG. 8. Low energy particle spectrum of radiations from iodine. (a) Normal antimony bombarded by alpha-particles; (b) antimony 123 bombarded by alpha-particles.

This research was assisted by the joint program of the ONR and AEC. The authors wish to thank Drs. B. D. Kern and D. J. Zaffarano who helped in the early stages of this investigation, and also Miss E. Lanterman for her help with the chemistry. They are also indebted to Dr. M. B. Sampson and the cyclotron crew for making the bombardments.

---

* *Note added in proof:* Drs. I. Perlman and L. Marquez have informed us that they obtained this activity from the reaction $Sb^{121}(\alpha,2n)I^{123}$. This isotope probably decays by K-electron capture to Te^{123} which emits the 159 kev gamma-ray. [See R. D. Hill, Phys. Rev. **76**, 186A (1949)].