Beta-Spectra of Co^{56}, Co^{57}, and Co^{58}

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For Co^{58} the 472-kev positron spectrum has been confirmed and the K conversion coefficient of the 805-kev gamma-ray has been found to be $(2.9\pm0.2)\times10^{-4}$. For Co^{57} the positron spectrum has been found to have an end-point energy of 320 ± 15 kev. Conversion electrons of 119-kev and 133-kev gamma-rays and a very soft (<18-kev) gamma-ray emitted by Fe^{57} have been observed. The K/L ratios of the 119-kev and the 133-kev gamma-rays have been estimated to be about 6.3 and 5.2, respectively. For Co^{56} two positron spectra have been observed, one having an end-point energy of 1.53 ± 0.02 Mev, the other having an end-point energy of 995 ± 25 kev.

INTRODUCTION

PREVIOUS investigations have shown that (1) Co^{58} has a 25-kev isomeric state[1] and disintegrates by emission of a 0.47-Mev positron (14.5 percent positron emission, 85.5 percent K capture[2]) to an excited state of Fe^{58} followed by an 805-kev gamma-ray,[3] the multipole order of which was found to be a mixture of magnetic dipole and electric quadrupole;[1] (2) Co^{57} disintegrates by emission of a 0.26-Mev positron[4] to an excited state of Fe^{57} which then makes transitions through two branches to the ground state. The K/L ratios of the 119-kev and the 131-kev gamma-rays emitted in these two branches indicated that both gamma-rays are electric octopole radiations;[5,6] (3) Co^{56} emits 1.50-Mev positron[6] to an excited state of Fe^{56}. There were six gamma-rays found due to transitions in Fe^{56}, ranging from 845 kev to 3.25 Mev.[6]

APPARATUS AND PROCEDURE

For the present study two Mn^{55} targets were bombarded in the cyclotron of the University of California, one with reduced and one with full beams of alpha-particles. The first target received 26.1 microampere hours of approximately 20-Mev alpha-particles, while the second target received 24 microampere hours of approximately 35.5-Mev alpha-particles.

About two months after receiving the radioactivity, a benzene extraction process was performed to separate the cobalt activity from the manganese residue. The sample of the target material was dissolved in $10N$ hydrochloric acid. A fraction of the sample was diluted to $1N$ hydrochloric acid, heated to 80°C and treated with 50 percent (by volume) acetic acid solution of alpha-nitroso beta-naphthol. After standing for 12 hours, the solution was extracted with benzene saturated with $1N$ hydrochloric acid. The benzene extract was washed with distilled water, and the former was evaporated to dryness. The residue was then ignited in a platinum crucible almost to an invisible quantity. The activity was finally transferred from the crucible by heating with concentrated hydrochloric acid. The solution thus obtained was made $6N$ and washed with ether to remove any iron that might be present. Following this the solution was reduced to almost dryness and taken up in $1N$ hydrochloric acid and treated a second and third time as described above for purpose of repurification. Following the third repurification the sample was deposited on a rubber hydrochloride film and mounted in a solenoid type spectrometer for investigation of the beta-spectra of cobalt activity.

The spectrometer was equipped with a thin window Geiger-Müller tube which could pass electrons of energy down to 16 kev. The instrument was calibrated with Cs^{137}, I^{131}, S^{35}, P^{32}, and Y^{90}, giving undistorted spectra down to at least 50 kev for thin sources. The resolution setting was 1.5 percent.

EXPERIMENTAL RESULTS

Figure 1 shows the momentum distribution curves for the radioactivity obtained from the low energy bombardment. Besides the continuous positron spectra, four conversion electron peaks have been observed. The two intense peaks are identified as being the conversion electron peaks of the 119-kev and the 133-kev gamma-rays emitted by the excited state of Fe^{57}.[5,6] In the high energy region a low intensity peak has been

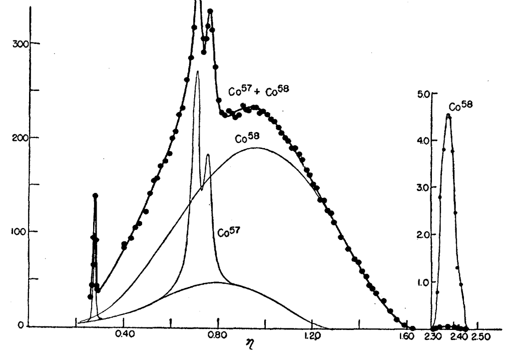

FIG. 1. Momentum distribution curves of Co^{57} and Co^{58}.

[1] K. Strauch, Phys. Rev. **79**, 487 (1950).
[2] Good, Peaslee, and Deutsch, Phys. Rev. **69**, 313 (1946).
[3] M. Deutsch and L. G. Elliot, Phys. Rev. **65**, 211 (1944).
[4] J. J. Livingood and G. J. Seaborg, Phys. Rev. **60**, 913 (1941).
[5] E. H. Plesset, Phys. Rev. **62**, 181 (1942).
[6] L. G. Elliot and M. Deutsch, Phys. Rev. **64**, 321 (1943).

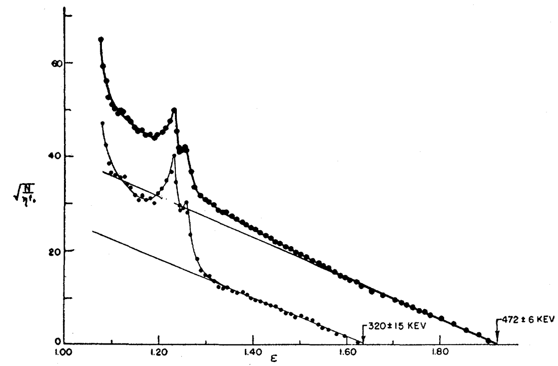

FIG. 2. Fermi plots of Co^{57} and Co^{58}.

observed which is identified as being the conversion electron peak of the 805-kev gamma-ray emitted by the excited state of Fe^{58}.[1] A low energy conversion electron peak has been observed, which, after making the tube window absorption correction to the counting rate in the low energy region, shows relatively high intensity. The energy of these conversion electrons has been estimated to be less than 18 kev. They may be identified as being the L conversion electrons going with the 14-kev gamma-ray emitted by the 0.11-μsec metastable state of Fe^{57}.[7]

Figure 2 shows the Fermi plots of Co^{57} and Co^{58}. Two components can be seen in the figure. The high energy component shows a straight line and has an end-point energy of 472±6 kev, which checks very well with the previously reported energy of the positron spectrum of Co^{58}.[1,3] The low energy component also shows a straight line and has an end-point energy of 320±15 kev, which is somewhat higher than the previously reported energy of the positron spectrum of Co^{57}.[4] By extrapolating the straight lines in the Fermi plot back to low energy region, it is possible to construct the momentum distribution curves for the two individual components. They are shown in Fig. 1 under the experimental distribution curve. By this the K conversion coefficient α_K of the 805-kev gamma-ray emitted following the 472-kev positron emission by the ground state of Co^{58} can be estimated to be $(2.8\pm0.2)\times10^{-4}$. Similarly the ratio of the number of K conversion electrons to the number of gamma-quanta of the 119-kev and the 133-kev gamma-rays emitted by the excited state of Fe^{57} can be estimated to be about 0.7, making use of Bethe and Bacher's formula[8] for the branching ratio of K capture to positron emission. Using Rose's table of K conversion coefficients,[9] the multipole orders can be assigned to these gamma-rays. It may be concluded that the 805-kev gamma-ray is an electric quadrupole radiation, while the 119-kev and the 133-kev gamma-rays probably are a mixture of magnetic quadrupole and electric octopole radiations. In addition, the K conversion coefficient of the 805-kev gamma-ray has also been estimated by comparing the number of its conversion electrons and the number of its photoelectrons ejected from a lead radiator. The α_K has been found to be $(3.0\pm0.25)\times10^{-4}$, which supports the assignment of electric quadrupole to the 805-kev gamma-ray.

Figure 3 shows the conversion electron spectrum of the 119-kev and the 133-kev gamma-rays emitted by the excited state of Fe^{57}. As pointed out by Kelly,[10] the monochromatic electron peak can be fitted on the low energy side by an exponential function and on the high energy side by a Gaussian distribution function. By this method it is possible to resolve approximately the K and L conversion electron peaks of each converted gamma-ray and thus to estimate K/L ratios. The K/L ratios of the 119-kev and the 133-kev gamma-rays have been estimated to be about 6.3 and 5.2, respectively.

Figure 4 shows the Fermi plot of the radioactivity obtained from the high energy bombardment. The highest energy component shows a straight line, having an end-point energy of 1.53±0.02 Mev, which agrees with the previously reported value within the experimental error.[6] The next highest energy component, subtraction of Fermi plot having been made, shows a slightly curved line with an end-point energy of 995±25 kev. Several runs have been made to check the shape of this component of the positron spectrum of Co^{56}. It appears that the curvature of the Fermi plot of this

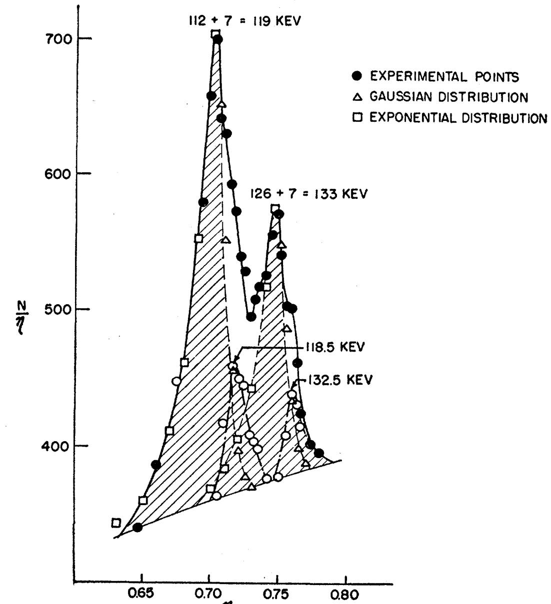

FIG. 3. Conversion electron peaks of 119-kev and 133-kev gamma-rays emitted by Co^{57}.

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[8] H. A. Bethe and R. F. Bacher, Revs. Modern Phys. 8, 184 (1936).
[9] Rose, Goertzel and Perry, Oak Ridge National Laboratory Report ORNL-1023 (1951) (unpublished).
[10] W. C. Kelly, Phys. Rev. 85, 101 (1952).

component is not prominent enough to assure any definite shape for the spectrum. In the low energy region of Fig. 4, the 472-kev positron spectrum of Co^{58} and the 320-kev positron spectrum of Co^{57} are also shown. From the Fermi plot and making an estimation of the theoretical branching ratio of K capture to positron emission,[8] it is possible to estimate the ratio of the number of disintegrations through 1.53-Mev positron emission (as well as the accompanying K capture) to the number of disintegrations through 995-kev positron emission (as well as the K capture). This ratio has been estimated to be 8:3.

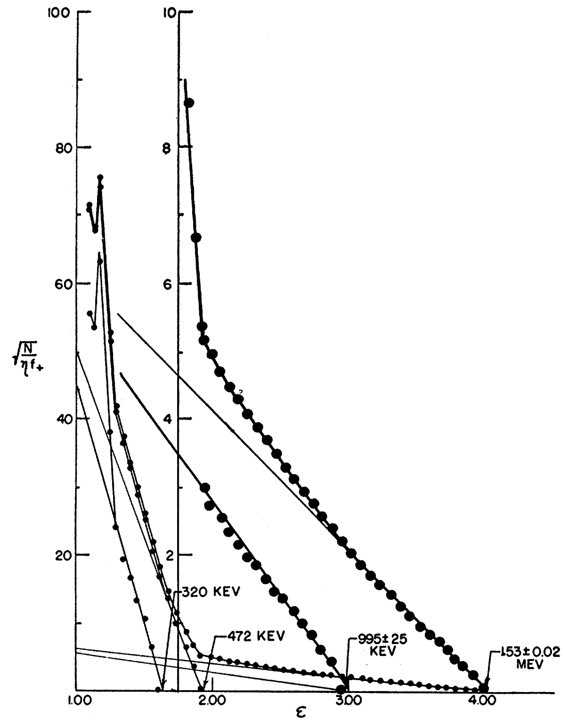

FIG. 4. Fermi plots of Co^{56}, Co^{57}, and Co^{58}.

DISCUSSION

For Co^{58} the logft value of the 472-kev positron emission is estimated to be 6.5, using Feenberg and Trigg's chart.[11] The beta-transition is thus expected to be first forbidden or L forbidden. The assignment of electric quadrupole radiation to the 805-kev gamma-transition is supported by the nuclear shell theory which explains the rule that for even-even nuclei the first excited state usually has spin two and even parity.[12]

For Co^{57} the logft value of the 320-kev positron emission is estimated to be 6.0 and expected to be first forbidden. The relative intensities, K/L ratios, and the ratio of the number of K-conversion electrons to the number of gamma-quanta of the 119-kev and the 133-kev gamma-rays seem to support the assignment of a mixture of magnetic quadrupole and electric octopole to the former and an electric octopole to the latter. In this case the <18-kev gamma-ray is a magnetic dipole radiation.

For Co^{56} the ratio between the numbers of disintegrations through the two positron emissions (as well as their respective accompanying K captures) has been estimated to be 8:3, while the ratio of the 1.24-Mev to the 1.74-Mev gamma-rays emitted by the excited state of Fe^{56} was found to be 5:2 by Elliot and Deutsch.[6] Thus it seems very likely that both the 1.53-Mev positron emission followed by a 1.24-Mev gamma-ray and the 995-kev positron emission followed by a 1.74-Mev gamma-ray lead to the first excited state of Fe^{56}. All other high energy gamma-rays[6] may be emitted due to transitions from still higher excited states of Fe^{56}, which can be reached by K capture of Co^{56}. In this case the logft values of the 1.53-Mev positron emission and the 995-kev positron emission are estimated to be greater than 8 and 7.5, respectively. Both positron emissions are then expected to be first forbidden.

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[12] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).