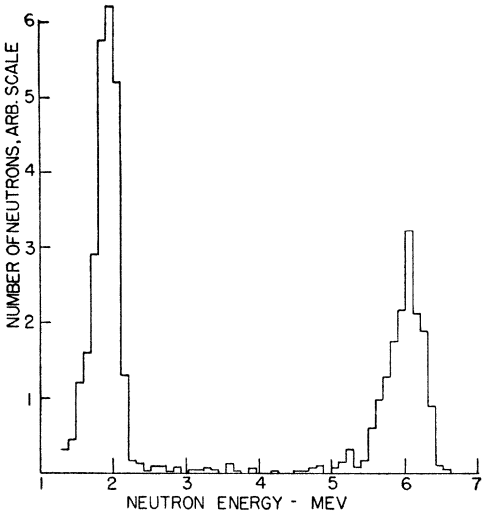

FIG. 1. Energy spectrum of neutrons from $Be^9(\alpha,n)C^{12}$.

Another excited state of C^{12} at about 3 Mev has sometimes been reported. There is no evidence of such a neutron group at this bombarding energy. We exposed another plate in the forward direction and 90 tracks were measured on it. It gave the same two groups of neutrons but in a different ratio of intensities. The low energy group was 0.4 times the intensity of the high energy group. The data shown in Fig. 1 gives 1.6 for this ratio. A further study of the angular distribution of the neutrons has been started in this laboratory.

[1] W. F. Hornyak and T. L. Lauritsen, Rev. Mod. Phys. **20**, 191 (1948).
[2] Lattes, Fowler, and Cuer, Nature **159**, 301 (1947).
[3] H. T. Richards, Phys. Rev. **59**, 796 (1941).
[4] M. S. Livingston and H. A. Bethe, Rev. Mod. Phys. **9**, 281 (1937).

The Natural Activity of Lanthanum

R. W. PRINGLE, S. STANDIL, AND K. I. ROULSTON
Physics Department, University of Manitoba, Canada
February 27, 1950

THE general criteria for beta-decay[1] indicate that of two nuclei Z^A and $(Z-1)^A$, the one with the greater atomic mass is unstable against beta-decay to the other. Thus the existence in nature of stable pairs of isobaric nuclei of neighboring atomic number is unlikely, and the occurrence of the exceptional pairs Z^A, $(Z-1)^A$ is accounted for as due to a very long half-life for beta-decay of the unstable member of the pair, because of nuclear spin and parity changes. The known beta-activities of K^{40} (1.4×10^9 years),[2] Re^{187} (4×10^{12} years),[3] Lu^{176} (2.4×10^{10} years),[4] and Rb^{87} (6.3×10^{10} years),[5] support this view, but there exist also the pairs (Sb^{123}, Te^{123}), (In^{115}, Sn^{115}), and (Cd^{113}, In^{113}), and the double anomalies[6] (Ba^{138}, La^{138}, Ce^{138}) and[7,8] (T^{50}, V^{50}, Cr^{50}) for which no activities have yet been observed due to extremely long lifetimes, the very low energy of the disintegration, or the difficulty of detecting K-capture processes when the specific activity is low. It is of interest to point out also that La^{138} and V^{50} are the only apparently stable odd-odd nuclei above N^{14}.

The recent development of a scintillation gamma-ray spectrometer of extreme sensitivity[9,10] means that a method is now available by which gamma-radiation due to a possible activity might be detected from a large mass of the isotope to be examined, and its energy analyzed to indicate whether the radiation could be due to minute traces of impurities (Th, U, K). Initial tests were made with materials of ordinary purity and feeble activities were observed which might be attributed to thorium contamination. However, these usually disappeared when extremely pure materials were used, as in the case of cerous oxalate from which impurities were removed by several hydrolysis.[11] We wish, nevertheless, to report an activity obtained with lanthanum which could not be removed in this way even after treatment in an ion exchange column to remove traces of rare earth metals, and which could not be identified as being due to any likely contaminant. The material was used in the form of 39 g of lanthanum trioxide, in an arrangement similar to the one with which we recently investigated the gamma-ray activity of potassium.[10] Figure 1

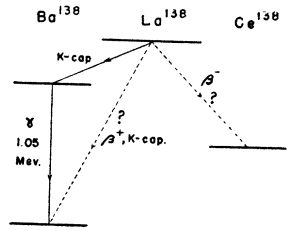

FIG. 2. Suggested disintegration scheme for La^{138} (half-life $\leqslant 1.2\times10^{11}$ years).

gives the differential pulse height distribution, corrected for background, of the secondary electrons produced by the gamma-radiation in the crystal, and the background curve for reference. The distribution has been compared with similar curves for K^{40} and Co^{60}, and from the approach to the axis[10] it would appear that the main component is a gamma-ray of energy (1.05±0.05) Mev. The rise in the distribution curve at low energies is due to degenerate radiation and the loss of electrons from the surfaces of the crystal. However, it is not impossible that a low energy component is also present.

We have estimated the number of gamma-quanta of energy 1.05 Mev to be (0.7±0.1) quanta/sec.-g of ordinary lanthanum, and have used data obtained with potassium to check the result. If we use the known abundance of La^{138} (0.086 percent) in lanthanum,[6] we obtain a half-life of 1.2×10^{11} years for the disintegration of La^{138}, assuming that one gamma-ray accompanies each disintegration. This period therefore represents an upper limit to the half-life. A search has been made with a thin window beta-counter (1 mg/cm²) for negative electrons or positrons from a source of lanthanum trioxide 100 mg/cm² thick. Any particles present of energy 100 kev or more must be in amount less than 0.4 per sec. per gram of lanthanum. It seems likely therefore that the 1.05 Mev gamma-ray is associated with a K-capture process to Ba^{138} (Fig. 2). It is worth while pointing out that no information is yet available on the spins of the nuclei involved. No attempt has yet been made to detect this K-capture directly. The examination of the other anomalous groups for possible activities is being continued.

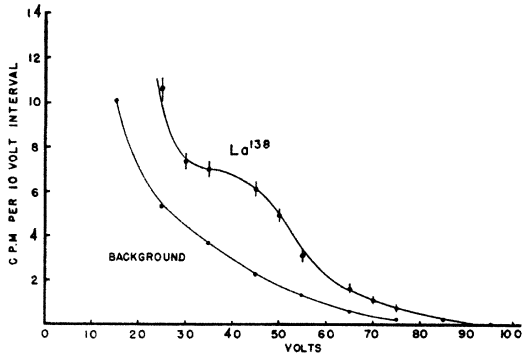

FIG. 1. Scintillation spectrometer study of the gamma-ray activity of lanthanum.

Our thanks are due the National Research Council of Canada for financial support of some of this work.

[1] L. Rosenfeld, *Nuclear Forces* (Interscience Publishers, Inc., New York), Chapter 3.
[2] See for example, E. Gleditsch and T. Graf, Phys. Rev. **72**, 640 (1947).
[3] S. N. Naldrett and W. F. Libby, Phys. Rev. **73**, 487 (1948).
[4] A. Flammersfeld, Zeits. f. Naturforschung **2**, 86 (1947).
[5] S. Eklund, Arkiv 33A, No. 14 (1945).
[6] Inghram, Hayden, and Hess, Phys. Rev. **72**, 967 (1947).
[7] D. C. Hess and M. C. Ingrham, Phys. Rev. **76**, 1717 (1949).
[8] W. T. Leland, Phys. Rev. **76**, 1722 (1949).
[9] Pringle, Roulston, and Taylor, Rev. Sci. Inst. (April, 1950).
[10] Pringle, Standil, and Roulston, Phys. Rev. **77**, 841 (1950).
[11] We are extremely grateful to Dr. D. S. Russell and Dr. Fitch of the Chemistry Division, N.R.C., Ottawa, for their cooperation in this work.

Gamma-Rays from Terbium 160*

J. M. Cork, C. E. Branyan, W. C. Rutledge, A. E. Stoddard, and J. M. LeBlanc
Department of Physics, University of Michigan, Ann Arbor, Michigan
March 20, 1950

THE radioactivity of terbium 160, produced by neutron capture, was first reported[1] by Bothe as having a half-life of 73.5 days. Subsequently a specimen irradiated in the Oak Ridge pile was shown[2] to emit many electrons by the internal conversion of gamma-rays. Further spectrometric studies on a highly purified sample kindly made available by Dr. G. E. Boyd of the Oak Ridge National Laboratory, show all the lines previously observed and many additional electron lines. Photographic spectra have been obtained both by internal conversion and by photo-emission in lead and uranium.

A summary of the energies of the conversion electrons and the photo-electrons from lead is presented in Table I, together with their interpretation and the energy sums. The gamma-energies are shown collectively in Table II.

TABLE I. Electron energies from terbium 160.

Electron energy	Interpretation	Energy sum	Electron energy	Interpretation	Energy sum
32.9 kev	K^1	86.3 kev	194.7 kev	M^4	196.6 kev
36.9	Auger L	44.9	205.3	L^5	214.4
39.5	K^2	93.0	209.6	Ph–K^7	297.5
42.3	Auger M	44.4	228.0	K^6	281.7
71.0	Ph–$L_{1,2}^1$	86.2	243.4	K^7	297.6
73.4	Ph–L_3^1	86.4	273.0	L^6	282.1
76.3	Ph–L_1^2	92.1	282.4	Ph–L^7	297.6
78.0	$L_{1,2}^1$	86.6	289.0	L^7	298.1
79.0	L_3^1	86.8	293.5	Ph–M^7	297.4
82.5	Ph–M^1	86.4	296.0	M^7	298.0
84.7	M^1	86.6	303.0	Ph–K^9	390.9
86.1	N^1	86.5	321.6	K^8	375.2
108.4	Ph–K^4	196.3	356.6	K^{10}	410.3
122.5	K^3	176.2	788.4	Ph–K^{11}	876.3
127.3	Ph–K^5	215.2	823.0	K^{11}	876.0
143.0	K^4	196.6	866.0	L^{11}	875.0
161.4	K^5	215.1	873.7	Ph–K^{12}	961.6
168.0	L^3	176.6	908.0	K^{12}	961.7
180.8	Ph–L^4	196.6	953.0	L^{12}	962.0
187.0	L^4	196.2			

The 12 gamma-rays may be arranged on a rather simple level scheme as shown in Fig. 1. The observed and expected energies

TABLE II. Summary of the gamma-rays in dysprosium 160.

Arbitrary number	Energy kev	Arbitrary number	Energy kev
γ^1	86.5	γ^7	297.8
γ^2	92.6	γ^8	375.2
γ^3	176.2	γ^9	391.0
γ^4	196.4	γ^{10}	410.3
γ^5	214.7	γ^{11}	876
γ^6	282.0	γ^{12}	962

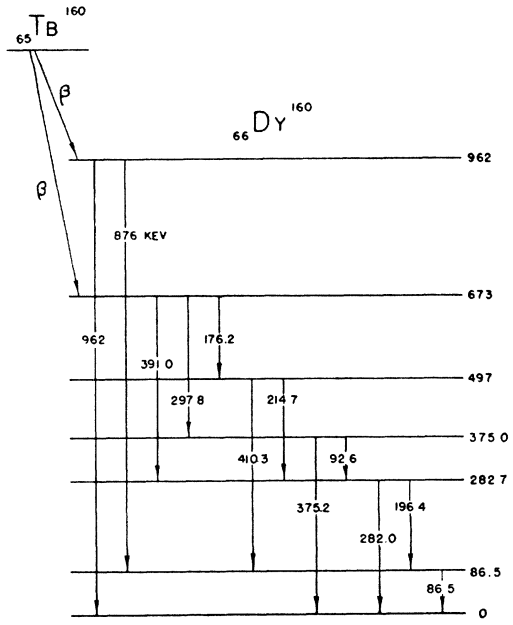

FIG. 1. Energy levels in dysprosium 160, following beta-emission from terbium 160.

for the possible transitions agree well within the experimental limits of accuracy. It is believed that the beta-spectrum consists of at least two electron groups whose maximum energies were reported first[2] as 882 and 546 kev and later[3] as 860, 521, and 396 kev, indicating a possible third group. The level scheme in Fig. 1 would be compatible with two beta-energies whose difference is slightly less than either of the reported sets of values as indicated. The beta-energy of lowest value would probably be accompanied by a gamma-ray of very high energy only slightly converted and hence not observable with the sample intensity available.

The half-life of the highly purified specimen followed through three octaves is found to be 76.0 days, confirming our previous report.

* This investigation was made possible by the joint support of the AEC and the ONR.
[1] W. Bothe, Naturwiss. **31**, 551 (1943); Zeits. f. Naturforschung **1**, 173 (1946); Krisberg, Pool, and Hibdon, Phys. Rev. **74**, 44 (1948).
[2] Cork, Shreffler, and Fowler, Phys. Rev. **74**, 240 (1948).
[3] Burson, Blair, and Saxon, Phys. Rev. **77**, 403 (1950).

Thermoelectric Voltage in Lead Telluride*

Ralph Wyrick and Henry Levinstein
Syracuse University, Syracuse, New York
March 6, 1950

WHEN an evaporated lead telluride film containing excess tellurium is baked in a vacuum, the resistance is first found to rise and after continued baking begins to drop. The thermoelectric power for the same film rises at first, then drops to zero at the resistance maximum, then reverses. The behavior of a particular lead telluride film is shown in Fig. 1. It is similar to the effect in lead sulfide observed by Hintenburger.[1] When lead telluride contains an excess of telliurium, conduction is by positive holes as is indicated by the positive thermoelectric voltage. Baking removes tellurium from the film. When stochiometric proportions are reached the thermal voltage reduces to zero and the