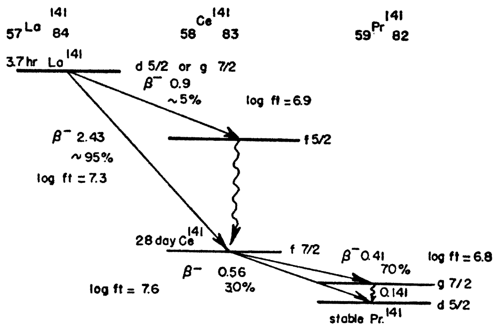

FIG. 2. Decay scheme of La^{141}.

by an impurity. The gamma-radiation from the source was examined with a sodium iodide crystal scintillation counter and pulse height selector. There appeared to be a gamma-ray of low intensity which decayed with a 3.7-hour half-life at approximately 1.3 to 1.6 Mev, but accurate measurements were not possible in the presence of the numerous gamma-rays from the small amounts of La^{140} and La^{142} unavoidably present in the sample. Beta-gamma coincidences, subject to the same difficulties, were observed at a rate which compared to Sc^{46}, was consistent with a beta-branch of 5 percent in La^{141}. The only coincidences observed were with betas of energy less than 1.5 Mev.

After the decay of the La^{141}, the gamma-rays from the Ce^{141} formed in one of the spectrometer sources were examined with the scintillation counter. The 0.14-Mev gamma-ray was found, but no others were observed between 0.3 and 0.6 Mev.[4] If present, such gamma-rays could not have had intensities greater than 0.5 percent of that of the 0.14-Mev gamma-ray. Prompt beta-gamma coincidences were found, indicating that the 0.14-Mev gamma-ray follows a beta-branch.

These data are consistent with the decay scheme shown in Fig. 2. The levels shown for Ce^{141} are taken from the summary of previous work in the National Bureau of Standards Circular 499. The spin of the stable Pr^{141} has been experimentally determined[5] and the other spins have been chosen to agree with the beta-decay data and the nuclear shell model of M. G. Mayer.[6]

We are indebted to many members of the Los Alamos Laboratory for help with these experiments, particularly to Dr. B. E. Watt and Dr. B. C. Diven.

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A Further Study of the Natural Activity of Lanthanum

R. W. PRINGLE, S. STANDIL, H. W. TAYLOR, AND G. FRYER
Physics Department, University of Manitoba, Winnipeg, Canada
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IN an earlier communication[1] it was announced that an activity due to the naturally occurring La^{138} isotope had been found in a search which was prompted by the isobaric relation of La^{138} to the nuclei Ba^{138} and Ce^{138}. In this investigation a scintillation spectrometer of low resolution was used to test the possibility of a gamma-radiation associated with such an activity, and it was estimated that ordinary lanthanum gave rise to 0.7 quanta/sec-g of energy 1.05 Mev although it was recognized that softer components might also be present. No search was made for the x-radiation which would be associated with a K capture process, but the absence of electrons or positrons suggested that the gamma-ray was to be associated with a K capture process to Ba^{138}.

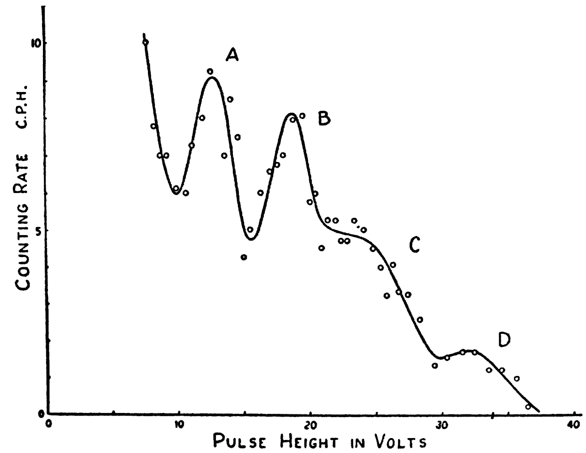

FIG. 1. Scintillation spectrometer pulse height distribution for the gamma-radiation of lanthanum, obtained with a five-channel kicksorter.

A further study of this activity has recently been made with a scintillation spectrometer of improved resolution to determine whether the initial activity could have been due to some unsuspected short-lived contaminant, and also to investigate the possible complexity of the gamma-ray spectrum. The same highly purified 39 g La_2O_3 source was used, and surrounded a $\frac{3}{4}$-inch cube NaI-Tl crystal mounted on an E.M.I. 5311 photomultiplier. The spectrometer was enclosed in a 3-in. lead castle. The resulting pulse height distribution (Fig. 1), obtained with a Harwell Type 1074A five-channel kicksorter, gives three lines A, B, and D, attributed to gamma-rays of energy 535±15 kev, 807±15 kev, and 1390±30 kev in terms of the known gamma-radiation of I^{131} and Co^{60}, used for calibration. The feature at C corresponds to the 1390-kev gamma-ray Compton edge at approximately 1100 kev, and in the earlier low resolution experiment[1] had appeared to give the gamma-

FIG. 2. Oscillogram of the scintillation spectrometer pulse height distribution for the gamma-radiation of lanthanum.

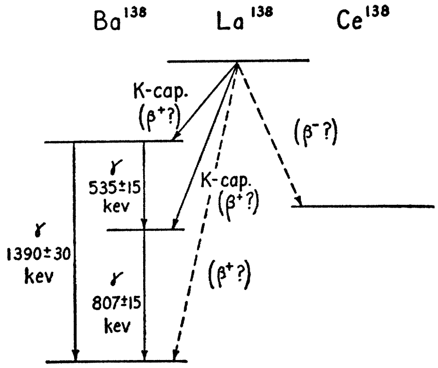

FIG. 3. Suggested disintegration scheme for La^{138} (half-life 2.0×10^{11} years).

ray spectrum end point. The distribution of Fig. 1 has been confirmed by photography of the spectrometer pulse height distribution displayed on the screen of a Tektronix 511A oscilloscope. Figure 2 corresponds to a 40 hour exposure at f:4.5 with fast ortho film. The top line in this spectrum is due to the 1390-kev gamma-ray, and below we have a broad band corresponding to the Compton distribution marked C in Fig. 1, and two sharper lines at 807 kev and 535 kev. A halo is observed on the film due to light coming from the oscilloscope filament.

Use was made of the known variation of instrumental detection sensitivity with gamma-ray energy to estimate the relative intensities of the gamma-rays at 1390 kev, 807 kev, and 535 kev as 1:0.65:0.3, respectively. If we recognize that, within the limits of error for the measurement of the gamma-ray energy, the 1390-kev gamma-ray appears to correspond to a crossover transition, we are then led to a decay scheme of the form given in Fig. 3, in which the gamma-rays have been associated with a K capture process to Ba^{138}. A search for electrons or positrons with a thin window Geiger counter indicated that the number of these particles with energy greater than 100 kev is less than 0.2/sec-g of ordinary lanthanum. On the basis of the proposed gamma-ray transitions of Fig. 3 and their estimated relative intensities, the activity of La^{138} has been estimated at approximately 0.45 disintegations/sec-g of ordinary lanthanum, corresponding to 0.6 gamma quanta/sec-g of all energies. In obtaining this latter figure a comparison of the observed gamma-activity was made to the gamma-activity of a known mass of potassium salt (giving rise to 3.3 gamma-quanta/sec-g.[2]

It remained to find evidence for the proposed decay scheme of Fig. 3 in the Ba x-rays which should accompany the K capture process. Figure 4 gives the result of a search for this radiation in which the height distribution of the scintillation spectrometer pulses was examined in the region of 30 kev. For calibration and comparison the 29-kev x-ray following the decay of I^{131} is also given in Fig. 4. We are led to the conclusion that an x-radiation of energy 32±1 kev is associated with the decay of La^{138}, a value which corresponds better to the Ba x-ray line at 31.4 kev than to the 33.7 kev x-ray line of Ce which might arise if La^{138} decayed by beta-emission to Ce^{138}. In order to estimate the number of x-rays emitted, a much smaller sample ($\frac{1}{3}$ g) was used, and a value of approximately 0.4 x-rays/sec-g of ordinary lanthanum was found, in good agreement with the number to be expected on the basis of the proposed decay scheme. We conclude that the half life of La^{138} is approximately 2.0×10^{11} years.

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

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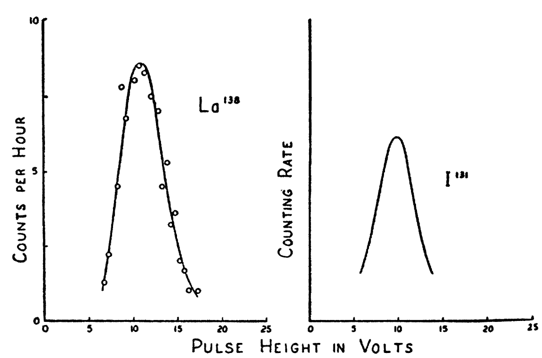

FIG. 4. Scintillation spectrometer pulse height distributions in the x-ray region, showing (left) the 32-kev radiation associated with the natural activity of lanthanum, and (right) the x-radiation associated with the decay of I^{131} for calibration.

Coincidence Studies in the Decay of La^{140}*

BEROL L. ROBINSON† AND LEON MADANSKY
Johns Hopkins University, Baltimore, Maryland
(Received October 5, 1951)

PREVIOUS work on the decay of La^{140} has been confined largely to energy determinations.[1-3] The coincidence experiments that have been reported were absorption measurements[4] performed with Geiger counters. Two different decay schemes have been proposed.[1,2] Therefore it might be of interest to investigate the decay of this isotope using the new techniques based on the proportional properties of scintillation detectors.[5]

A sample of La^{140} was obtained by neutron irradiation of lanthanum oxide in the Oak Ridge pile. Using a thick source (~0.1 g/cm^2) a beta-gamma coincidence experiment was performed. The beta-ray detector has been described elsewhere.[6] The gamma-rays were detected in a 3-cm cube of NaI(Tl). This experiment indicated that the 1.60-Mev gamma-ray is in coincidence with the most energetic beta-rays. Gamma-gamma coincidence experiments showed that the 1.60-Mev and 0.82-Mev gamma-rays are coincident.

The angular correlation[6-8] between these two gamma-rays was also investigated. Again the 1.60-Mev quantum was detected in a 3-cm cube of NaI(Tl). One discriminator was set to accept those pulses in the unresolved "Compton plus photoelectric" peak of the pulse-height spectrum. The 0.82-Mev quantum was detected in a cleaved piece of NaI(Tl) having dimensions $\frac{5}{8}$ in.×$\frac{5}{8}$ in.×$\frac{1}{8}$ in. The pulse-height spectrum from the thin crystal showed a strong photoelectric peak for the 0.82-Mev gamma. A second discriminator was set to accept this (0.82-Mev) photoelectric peak. The outputs of the discriminators were fed to a coincidence circuit. Parallel channels of fast amplifiers and a fast coincidence circuit served to reduce the accidental coincidence rate by requiring a fourfold coincidence. Some 2-3000 fourfold coincidences were counted at each of four angles. The results are shown in Table I.

We may begin to build a decay scheme by observing that the most energetic beta-ray branch of energy 2.26 Mev,[1] is followed by the 1.60-Mev gamma-ray; probably to the ground state of Ce^{140}. The softer beta-ray branches[1] must lead to the 1.60-Mev level through the emission of the 0.82-Mev gamma-ray, and to other levels of Ce^{140} through the emission of the other gamma-rays which have been observed.[1-3] We assume a partial decay scheme

TABLE I. Angular correlation of La^{140} gamma-rays.

	$W(90°)$	$W(120°)$	$W(150°)$	$W(180°)$
Experiment	1	1.016±0.027	1.146±0.031	1.147±0.033
Theory (see text for assumptions)	1	1.033	1.112	1.157

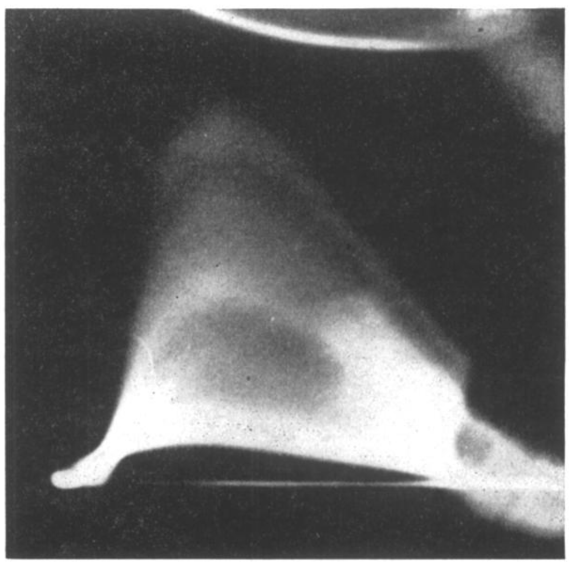

FIG. 2. Oscillogram of the scintillation spectrometer pulse height distribution for the gamma-radiation of lanthanum.