mass as a function of θ, the angle in the center of mass:

$$(d\sigma/d\Omega)_{cm}=(3.20\pm0.78)(0.071\pm0.068+\cos^2\theta)\times10^{-29}\ \text{cm}^2\ \text{sterad}^{-1}.$$

The total cross section for the mesons in the peak is therefore $(1.62\pm0.49)\times10^{-28}$ cm². This suggests that the meson comes off almost entirely in a P-wave, and since the majority of the mesons of the entire spectrum are in the peak, it would follow that the total spectrum is approximately in a P-wave.

It is a pleasure to acknowledge the continued encouragement we have received from Professors E. O. Lawrence and R. L. Thornton. Mr. Dan Hamlin was of great help with the scanning of the plates. We are indebted to Dr. K. M. Watson and Mr. E. M. Henley for discussions of the theoretical aspects of the problem. We would like to thank Mr. J. Vale and the cyclotron crew for making the bombardments.

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The Radioactivity of Barium 140

J. M. Cork, J. M. LeBlanc, A. E. Stoddard, D. W. Martin, C. E. Branyan, and W. J. Childs
*University of Michigan, Ann Arbor, Michigan**
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RADIOACTIVE barium of half-life about 13 days was first noted[1] as a product of the bombardment of uranium by neutrons, even before the phenomenon of nuclear fission was recognized. Subsequent studies[2] have shown the activity to be in Ba^{140}, in which the beta-decay to La^{140} is complex and accompanied by gamma-emission. Three gamma-rays had been reported[3] with energies of 0.16, 0.30, and 0.54 Mev.

TABLE I. Summary of electron lines.

Electron energy (kev)	Relative intensity	Interpretation	Gamma-energy (kev)
23.3	20	$L_1^1(Z=57)$	29.6
23.7	2	L_2^1	29.6
24.1	1	L_3^1	29.6
28.2	10	M^1	29.6
29.3	5	N^1	29.6
79.8	1	K^2	118.5
93.1	4	K^3	131.8
123.3	10	K^4	162.0
156.0	5	L^4	162.3
160.8	2	M^4	162.2
265.5	4	K^5	304.2
382.8	1	K^6	421.5
397.1	1	K^7	435.8
498.0	4	K^8	536.7
530.0	1	L^8	536.3

A continued study of the fission product as supplied by the Oak Ridge National Laboratory, using photographic magnetic spectrometers, leads to a more accurate evaluation of energies and shows the existence of certain previously unreported gamma-rays. The barium radioactivity will usually be in equilibrium with the daughter, radioactive lanthanum. It appears, however, that in the original chemical separation of Ba^{140}, the La^{140} is carried down in excess of the equilibrium amount. This leads to a change in the relative intensity with time of the electron lines due to La^{140} as compared with the electron lines due to Ba^{140} and thus aids in their identification. The half-life curve of the specimen is complex, showing an initial 41-hour decay before settling into the longer barium half-life, now found to be 13.4 days. The K-L-M differences of the electron energies also make it possible, in most cases, to distinguish those electron lines associated with each activity.

A summary of the electron energies (believed to be accurate to ±0.2 percent) together with an arbitrary estimate of their relative intensities, and proposed gamma-origin is presented in Table I. A decay scheme had been proposed by Beach *et al.*, using their three observed gamma-energies, in which an unobserved gamma of 76 kev would have been required. It is now quite certain this gamma-ray does not exist. The observed gamma-energies do, however, fit very satisfactorily a modification and enlargement of the level scheme as shown in Fig. 1. The gamma-rays of greater intensity are represented as transitions with darker lines. The transitions shown as dotted lines are less certain, since only the "K" electron line was observed for each of these gamma-rays and there is some possibility that any or all of this activity is in the daughter product. In order to complete the scheme a gamma-ray of energy 14 kev would be required. This energy is slightly below the limit of the spectrometers.

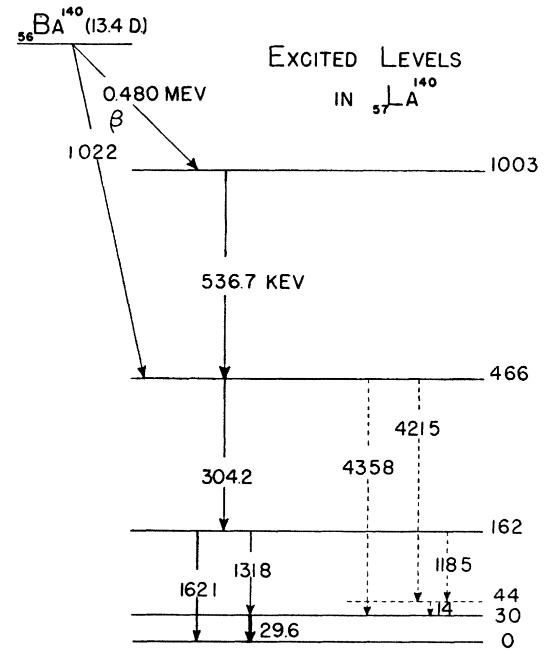

FIG. 1. Energy levels in La^{140} following beta-emission from Ba^{140}.

* This project received the joint support of the ONR and AEC.

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Gamma-Radiation from Lanthanum 140

J. M. Cork, A. E. Stoddard, J. M. LeBlanc, C. E. Branyan, D. W. Martin, and W. J. Childs
*University of Michigan, Ann Arbor, Michigan**
(Received June 28, 1951)

A PREVIOUS study of the radioactivity from La^{140} (41.4 hr) showed[1] the presence of twelve low energy gamma-rays, with an indication of others at higher energy. A contemporary report noted[2] the beta-decay of La^{140} to be complex with energies of 1.32, 1.67, and 2.26 Mev; but only five gamma-rays, mainly at higher energy, were found. The present spectrometric investigation,

TABLE I. Electron energies from La^{140}.

Electron energy (kev)	Relative intensity	Interpretation	Gamma-energy (kev)
62.1	2	$L_I^1(Z=58)$	68.7
68.9	4	K^2	109.2
70.1	1	K^3	110.4
90.3	7	K^4	130.6
102.7	4	L_I^2	109.3
108.0	1	M^2	109.3
124.3	1	L_I^4	130.9
132.7	2	K^5	173.0
201.1	3	K^6	241.4
225.1	3	K^7	265.4
288.3	10	K^8	328.6
322.0	4	L_I^8	328.6
326.0	1	M^8	327.4
391.0	2	K^9	431.3
446.0	7	K^{10}	486.3
480.0	2	L_I^{10}	486.6
484.9	1	M^{10}	486.3
711.5	1	K^{11}	751.8
775.5	5	K^{12}	815.8
808.2	1	L_I^{12}	814.8
886	1	K^{13}	926
1557	3	K^{14}	1597
1591	1	L_I^{14}	1598
1864	1	K^{15}	1904

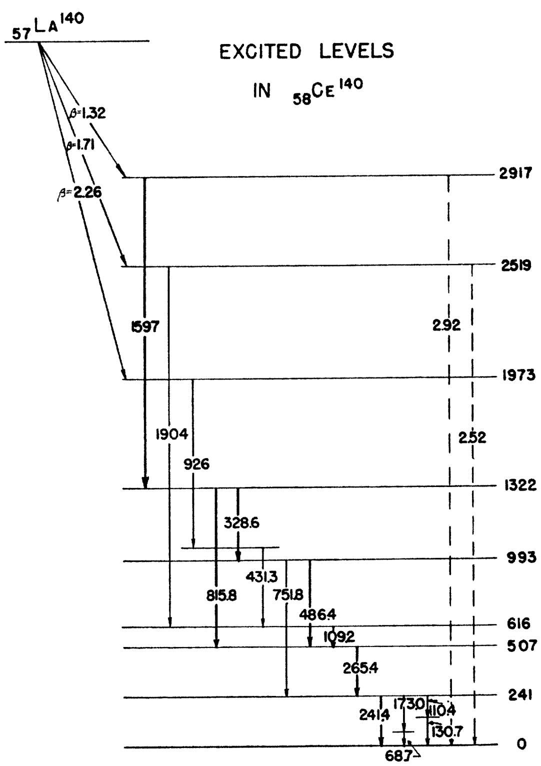

FIG. 1. Nuclear levels in Ce^{140} following beta-decay in La^{140}.

TABLE II. Gamma-energies.

Arbitrary designation	Energy (kev)	Arbitrary designation	Energy (kev)
1	68.7	10	486.4
2	109.2	11	751.8
3	110.4	12	815.8
4	130.7	13	926
5	173.0	14	1597
6	241.4	15	1904
7	265.4	16	(2.52 Mev)
8	328.6	17	(2.92 Mev)
9	431.3		

employing a stronger source obtained as a fission product from the Oak Ridge National Laboratory, closely confirms most of our earlier interpretation and adds several previously unobserved gamma-rays.

A summary of the energies of the conversion electron lines, together with their approximate intensities and interpretation, is presented in Table I. The averaged values of the derived gamma-rays, shown in column 4, are collected in Table II, each designated by an arbitrary index number. The gamma-rays fit remarkably well a nuclear level scheme as shown in Fig. 1. The high energy gamma-rays previously reported at 2.5 Mev by Wattenberg and at 2.9 Mev by Bishop are included as 2.52 and 2.92 Mev, since as such they appear as cross-overs in the proposed level scheme, although they were not observed by conversion electrons.

* This project received the joint support of the AEC and ONR.

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The Application of Wooldridge's Theory of Secondary Emission*

E. M. BAROODY
Battelle Memorial Institute, Columbus, Ohio
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An interesting letter by Brophy[1] has pointed out how Wooldridge's result[2] for the variation of the secondary emission coefficient with primary energy can be put into a very convenient form, and has compared this result with a particular form of free electron theory, and with experiment. We have been working along similar lines and have reached conclusions in general agreement with those of Brophy. However, there are certain differences and extensions which are presented below.

There seems to be an error in the form of Wooldridge's Eq. (53) as first given in the letter. It becomes correct if δ_{max} is replaced by δ_∞, the value which Wooldridge's δ would approach for large primary energy. The corresponding definition of K is $(1/2\delta_\infty)\times[1-(W_a/E_0+E_F)^{\frac{1}{2}}]$. The other substitutions listed by Brophy then lead to

$$\delta/\delta_\infty = 1 - A\exp(-x^2) + B\exp(-x^2)\int_0^x \exp(t^2)dt, \qquad (1)$$

where A, B, and M are defined in Brophy's letter,[3] and $\delta_\infty=(1-M)/K$.

Various implications of the above relations have been investigated. It was found that δ reaches a maximum given by

$$\delta_{max}/\delta_\infty = 1 + (MK^{\frac{1}{2}}/x_{max}) \qquad (2)$$

at $x=x_{max}$, where

$$\int_0^{x_{max}} \exp(t^2)dt - \frac{\exp(x_{max}^2)}{2x_{max}} = \frac{A}{B}. \qquad (3)$$

Dividing Eq. (1) by Eq. (2) gives an equation for δ/δ_{max} which should replace Brophy's Eq. (2).

The extent to which this new statement of Wooldridge's result predicts a universal relationship between δ/δ_{max} and $E_p/E_{p\,max}$ has been explored. For most metals the parameter M may be estimated to fall in the range 0.75 to 0.90. The corresponding range of K is determined by the experimental values of δ_{max} almost all of which fall between 0.5 and 1.6. Calculation shows that for any reasonable values of M and K, a graph very much like the quantum-mechanical curve in Fig. 1 of Brophy's letter is obtained, although a significant variation in the rate of decrease at high energies is found. The amount of this variation is easily determined from the following approximation, which applies extremely well for all $E_p \geqslant E_{p\,max}$:

$$\delta/\delta_{max} = \{1+\gamma(E_{p\,max}/E_p)^{\frac{1}{2}}\}/(1+\gamma). \qquad (4)$$