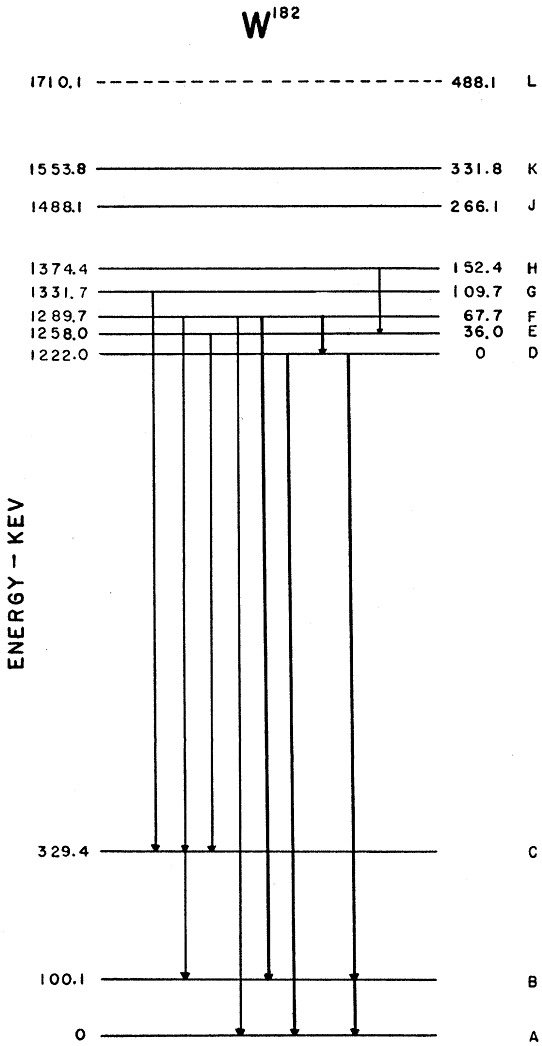

FIG. 1. Proposed energy levels in W^{182}. Transitions shown are discussed in text.

upwards to follow an approximate algebraic relation. Allowing for two additional levels, not shown on the figure for lack of accuracy, at approximately 5 and 205 kev above D, the level energies above D become asymptotic to the expression $E_L=3.70L(L+1)$. The correct energy values are shown on the right of the figure. The values of L are to be numbered consecutively from D, upward, starting with $L=1$ for the D level.

The levels A, B, and C agree well with the Bohr-Mottelson[2] formulation, with level C taken as 4+. A further level at 680±5 kev which can be justified from conversion line data would fit the third-excited state predicted by this formulation. It is interesting to note that the level D also fits, in energy, the fourth-excited state predicted by this theory, but the predicted spin value of 8 is manifestly at variance with the 1− assignment suggested above.

In addition to the papers previously mentioned, those of Beach *et al.*,[3] Cork *et al.*,[4] and Scharff-Goldhaber[5] were of considerable assistance.

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* Now with the National Bureau of Standards, Washington, D. C.
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Identification of Californium Isotopes 249, 250, 251, and 252 from Pile-Irradiated Plutonium*

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IN a recent communication[1] we reported a large spontaneous fission activity associated with the californium produced from plutonium irradiated with neutrons in the Materials Testing Reactor (MTR) at Arco, Idaho. The important implications of gross amounts of spontaneous fission activity prompts us to give additional information on the mass assignments and nuclear properties of several californium and berkelium isotopes. The heavy elements were chemically separated from two plutonium samples, I and II, which received integrated fluxes of 4×10^{21} and 8×10^{21} neutrons, respectively.

Californium from sample II was analyzed in a 12-inch, 60° mass spectrometer with a multiple filament source. Californium isotopes of mass numbers 249, 250, 251, and 252 were detected in mole percentages given in column 1 of Table I. A small quantity

TABLE I. Mass spectrometric analyses of two californium samples, giving isotopic abundances in mole percent.

Cf isotope	Sample II	Sample II′
Cf^{249}	4.3±0.5	28±7
Cf^{250}	49 ±6	34±8
Cf^{251}	11 ±3	8±1
Cf^{252}	36 ±5	30±3

of californium (corresponding to about four percent of the gross californium activity of sample II) was left with the berkelium activity for five weeks, after which time the californium was again chemically separated from the berkelium (this will be referred to as californium sample II′). The mass spectrometric analysis of this californium sample is given in column 2 of Table I. The Cf^{250}/Cf^{251}, Cf^{250}/Cf^{252}, and Cf^{251}/Cf^{252} mole ratios of the two samples are constant within statistical error. The Cf^{249} in sample II′ has, however, been enhanced. This is evidence for assigning to Cf^{249} the 5.81-Mev alpha particles observed to grow into a purified berkelium fraction and to chemically elute in the californium position. The alpha half-life of Cf^{249} is calculated to be 550±150 years from the 5.81-Mev alpha-particle growth rate into a Bk^{249} sample of a measured disintegration rate.

Alpha-pulse analysis of californium sample II by a wire-screen collimator technique[2] showed two prominent alpha groups of 6.12 and 6.03 Mev. The gross 6.12-Mev/6.03-Mev alpha activity ratios in samples I and II were 0.62±0.12 and 3.3±0.3, respectively. Gamma-alpha coincidence measurements on sample II showed a fine-structure peak associated with each of the two prominent californium ground-state alphas. The intensity ratio of the fine-structure peaks was also about 3.3. This behavior is characteristic of the alpha spectra of even-even nuclides.

Alpha-pulse analysis of the californium II′ sample showed 0.4±0.1 percent 5.81-Mev alphas. The spontaneous fission activity on a plate from sample II californium, containing ini-

TABLE II. Nuclear properties of some isotopes of elements 97 and 98.

Isotope	Radiation	Half-life	Alpha energy (Mev)	β^- energy (kev)	Spontaneous fission half-life
$_{97}Bk^{249}$	β^-, α (?) branching ratio $\beta^-/\alpha\approx10^5$	~1 year	5.4 ±0.1	100±20	$>10^7$ years
$_{98}Cf^{249}$	α	550±150 yr	5.81±0.03		$>10^6$ years
$_{98}Cf^{250}$	α	9.4±2.3 yr	6.03±0.01		$\geq10^4$ years
$_{98}Cf^{251}$	(α)				
$_{98}Cf^{252}$	α	2.1±0.4 yr	6.12±0.01		60±12 years
$_{98}Cf^{253}$	β^-	18±3 days			

tially 1375 fission disintegrations/minute, is decaying with a 2.1±0.4 year half-life. A summary of the nuclear properties of some isotopes of berkelium and californium are given in Table II. The decrease in spontaneous fission half-life of the heavy even-A californium isotopes agrees with recent predictions.[3]

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* Nuclear properties of some of these isotopes were measured in other work at Argonne National Laboratory, University of California Radiation Laboratory, and at Los Alamos Scientific Laboratory, not yet published [see also Thompson, Ghiorso, Harvey, and Chopping, Phys. Rev. **93**, 908 (1954)].

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Inelastic Scattering of 190-Mev Electrons in Beryllium*†‡

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In investigating the elastic scattering of high-energy electrons from various nuclei[1] we reported preliminary evidence of structure in the "elastic" profiles observed at 70° and 90° in beryllium at 125 Mev. We have re-examined this problem with a

Table I. Summary of data on elastic and inelastic peaks.

Angle \ Peak	A	B	C	$A-B$	$A-C$
60°	418.0	404.0	—	14.0	—
70°	413.6	400.0	378.4	13.6	35.2
90°	404.5	394.0	370.0	10.5	34.5
			Average	12.7±1.5	34.8±1.5

newly rewound analyzing magnet which permits studies up to 200 Mev. With incident electrons of 190 Mev in a band 1.0-Mev wide we have confirmed this structure and the details have now been more clearly revealed. Figure 1 shows the elastically scattered peak A and two additional inelastically scattered peaks B and C at 70° for a 100-mil beryllium target set at 45° with respect to the incident beam. The abscissa is given in terms of the settings of the potentiometer reading the current through the analyzing magnetic spectrometer. Figure 2 shows similar data at 90°. We have also observed inelastic scattering at 60° and have observed the peaks A and B, but unfortunately did not carry the observations below B to look for peak C. Table I shows the positions of the peaks at 90°, 70°, and 60° and also shows the differences $A-B$, $A-C$. These differences may be converted into the excitation energies of the levels excited in beryllium by 190-Mev electrons when the energy calibration of the abscissa is known. An initial calibration in terms of magnetic field measured at the center of the spectrometer trajectories gave the instantaneous slope of the curve of energy *versus* potentiometer setting as 0.20 Mev per division of potentiometer reading. Averaging the intervals $A-B$ and $A-C$ provides $A-B=12.7$ divisions or 2.54 Mev and $A-C=34.8$ divisions or 6.96 Mev. These values are in good agreement with those excitation levels reported by Britten,[2] and the single low-lying level of Davis and Hafner[3] and Rhoderick.[4] Britten's values are 2.5±0.2 Mev and 6.8±0.3 Mev. Britten's third level at 11.6 Mev was not sought.

The beryllium levels previously observed have been found by inelastic scattering of protons whereas these levels have now been

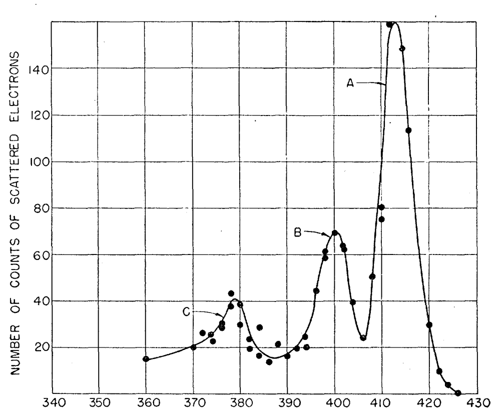

Fig. 1. Elastic peak (A) and first and second inelastic peaks (B and C) in beryllium at 70°.

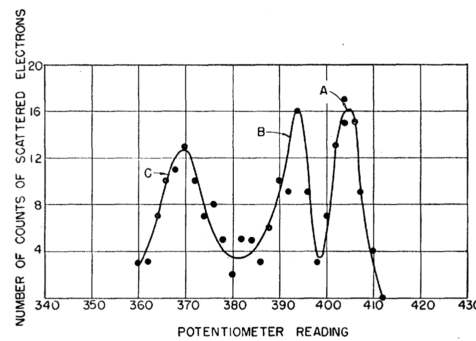

Fig. 2. Elastic peak (A) and first and second inelastic peaks (B and C) in beryllium at 90°.

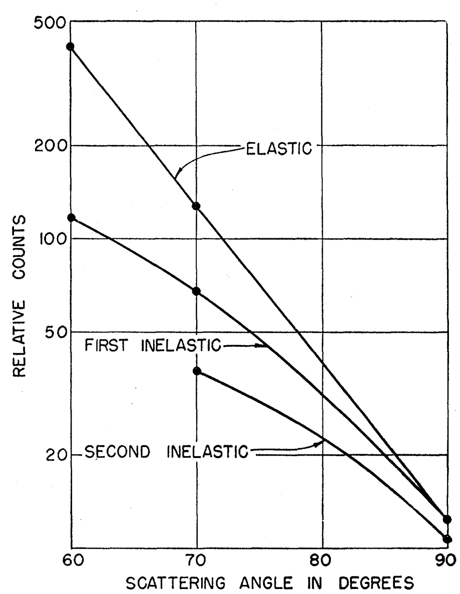

Fig. 3. Elastic and inelastic cross sections on a relative scale as a function of scattering angle.