expected, e.g., in the region of competition between the $(p_{3/2}f_{5/2})$, $(g_{9/2}p_{1/2})$, and $(g_{7/2}d_{5/2})$ orbitals.

There remains the general question of whether there is a systematic dependence of the unfavored factors on atomic number and on the position of N and Z with respect to the closure of shells or subshells. As for the general A dependence, we are inclined to say that there is none of statistical significance. It is true that in our range of A from 35 to 141 there are some U values below 10 for light elements (S^{35}, Sc^{43}, Ti^{45}, K^{38}) while at the upper edge they are slightly larger (Nd^{141}, Pm^{141}, La^{136}, Pr^{140}). However, there are also some low values in the intermediate range (Zn^{69}, Mo^{91}, Tc^{93}, Tc^{100}, Pd^{112}, In^{112}).

The influence of shell closures, which is definitely noticeable, seems to be an indirect one. If there are only very few particles or holes outside closed shells, then generally there is much less chance for configuration mixing, and the U values become comparatively small. On the other hand, closure of subshells seems to have as large an effect as the closure of major shells. This points to configuration mixing as the major cause for the fluctuations of U values, a finding that is supported by all the evidence presented here. Of course, the regions where mixing is most likely are also the ones with partly-filled shells, and thus of high deformability, and it may be that these effects are not nearly separable. However, calculations by one of the authors,[14] by Redlich and Wigner[15] and by Suekane[16] make it unlikely that orthogonality due to the cores being deformed differently in the initial and final states can explain a major part of the differences between the favored and unfavored transitions. It seems thus that, even for the purest shell-model configurations, there remains an unfavored factor of order three for the transition probabilities in β decay. It is our guess, and at this time a guess only, that this factor may be due to the two-particle correlations, which are not incorporated in the shell-model wave functions.

[14] W. C. Grayson, Jr. (unpublished).
[15] M. G. Redlich and E. P. Wigner, Phys. Rev. **95**, 122 (1954).
[16] S. Suekane, Progr. Theoret. Phys. (Japan) **10**, 480 (1953).

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Properties of Bk^{245}†

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The radiations of 5-day electron-capturing Bk^{245} were measured with electron spectrometer, scintillation spectrometer, and alpha pulse analyzer. Conversion electrons from 250-kev and ~390-kev transitions were observed. The electromagnetic spectrum contains L and K x-rays and 250- and 380-kev gamma rays. The relative contributions to the x-ray intensities from the primary capture processes and from excited state conversions were determined by counting coincidences between the electromagnetic radiations. Bk^{245} decays primarily by electron capture ($L/K=0.33$) to a 250-kev level in Cm^{245}. The K and L conversion coefficients of the 250-kev transition are 1.76 and 0.44, respectively, indicating that the transition is $M1$. About 6% branching decay goes to a level at 630 kev. The lifetimes of the excited states are less than 2×10^{-9} sec. The intensity of alpha-particle emission is 1.05×10^{-3} per disintegration (alpha half-life 13 yr). Three alpha groups were resolved: 5.89 Mev (26%), 6.17 Mev (41%), and 6.37 Mev (33%).

I. INTRODUCTION

A BERKELIUM isotope decaying principally by electron capture with a half-life of 4.95 ± 0.1 days has been reported by Hulet, Thompson, Ghiorso, and Street[1] and assigned to mass 245. Alpha-branching decay to the extent of about 0.1% was observed. Hulet[2] subsequently assigned L and K x-rays and 68- and 245-kev photons to the decay.

Within the past year milligram quantities of Am^{243} and Cm^{244} have become available at Argonne from plutonium irradiated in the Materials Testing Reactor.[3] With these quantities it appeared feasible to prepare sufficient quantities of Bk^{245} by the $Cm^{244}(d,n)Bk^{245}$ and $Am^{243}(\alpha,2n)Bk^{245}$ reactions to obtain more information about its disintegration processes.

II. EXPERIMENTAL

A. Bombardments and Purification

The curium target (96% Cm^{244}, 2% Cm^{245}, 2% Cm^{246}) was prepared by spreading curium nitrate solution containing about 1.5 mg of curium onto an aluminum backing, evaporating the solution to dryness, and decomposing the nitrate to the oxide in a muffle furnace at 600°C. The curium was covered with a one mil aluminum foil to reduce the alpha health hazard. The back of the target was water-cooled and the covering foil was air-cooled. The curium was bombarded for about fifteen hours at 120 μa in the external deuteron

† Work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Hulet, Thompson, Ghiorso, and Street, Phys. Rev. **84**, 366 (1951).
[2] E. K. Hulet, thesis, University of California Radiation Laboratory Report No. UCRL-2283, July, 1953 (unpublished).
[3] Stevens, Studier, Fields, Sellers, Friedman, Diamond, and Huizenga, Phys. Rev. **94**, 974 (1954).

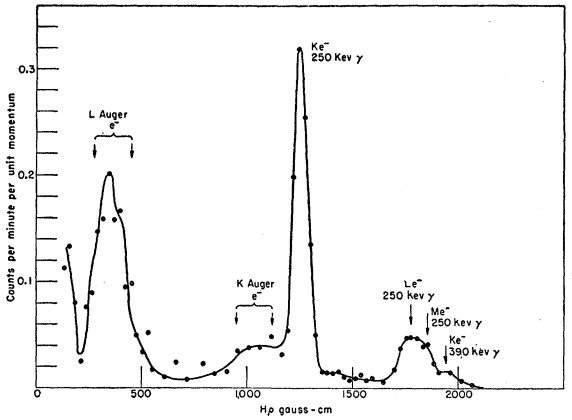

FIG. 1. Electron spectrum of Bk^{245}.

beam of the Argonne 60-in. cyclotron. After bombardment, the target was allowed to cool for eight hours to reduce the gamma radiation from impurities in the aluminum. The radiations of Bk^{243}, formed by the $(d,3n)$ reaction, were measured to trace the less active Bk^{245} through the chemical purification.

The Am^{243} target (99.99% Am^{243}, 0.01% Am^{241}) was prepared by evaporating an americium chloride solution containing 0.1 mg americium on a small copper block. The copper block, cooled by water, was placed in the tank of the cyclotron. The Am^{243} was bombarded for six hours by a circulating helium ion beam of about 40 μa. Bk^{246}, formed by the (α,n) reaction, served as a tracer in the purification.

The curium-berkelium mixture was dissolved from the target in concentrated nitric acid and precipitated as the hydroxide. The precipitate was dissolved, extracted in tributylphosphate, re-extracted into dilute hydrochloric acid, and adsorbed onto a ten-centimeter long Dowex 50 resin column. To reduce the effects of the bubbling due to peroxide formation by the high alpha activity, the internal diameter of the column was three millimeters and the column was mounted in a horizontal position. The activity was eluted with 0.25-molar ammonium glycolate solution at a pH of 4.0. The column separation reduced the curium to berkelium ratio by a factor of 10^5. The berkelium fraction was recycled through two more similar glycolate columns of twenty centimeters in length to reduce the Cm^{244} in the berkelium fraction to less than 0.05% by activity. The resulting berkelium activity was extracted into a 0.25M solution of thenoyltrifluoroacetone[4] in benzene and evaporated on a one-mil aluminum disk for alpha and gamma spectra.

The chemical procedure used in the Am^{243} bombardment was similar to the method described above. The horizontal column step was unnecessary because of the much smaller amount of alpha activity. The electron spectrum work described in Sec. I.B and associated gamma spectrometry was done on the berkelium prepared from this source.

The gross half-life of Bk^{245} was determined by following the decay with a thin window proportional counter. The half-life found was 4.98±0.02 days in good agreement with the value of 4.95 days given in previous work[1] and with the half-life obtained by following the decay of individual peaks in the alpha spectrum.

B. Electron Spectrum

A sample of berkelium was prepared for the Argonne double-lens beta spectrometer by drying a drop of berkelium nitrate solution on an aluminum foil of approximately 200 μg/cm^2 and heating to about 400°C. The source thus formed was about 5 mm in diameter. The baffles of the spectrometer were set to give about 5% transmission and 6.8% resolution (full width at half-height) for a 5-mm diameter source. The electron spectrum was surveyed from 3 kev to approximately 450 kev.

In addition to electrons attributable to Auger transitions, electrons corresponding in energy to conversion of a 250-kev gamma ray in the K and L (and M unresolved) shells and possibly to conversion of a 390-kev gamma in the K shell were detected. Figure 1 shows the momentum spectrum of the conversion lines. The spectrometer data, normalized by the transmission of the spectrometer and the appropriate decay correction to the intensity of K x-rays from the sample (see Sec. C), are given in Table I. No reliable estimate of the errors in the absolute values can be given. The ratio of K to $L+M$ electrons of the 250-kev transition is probably accurate to within 15 percent. The ratio of K conversion electron intensities of the 250- and 380-kev transitions may be in error by as much as 50%.

C. Electromagnetic Radiations

Electromagnetic spectra were observed with the same sample used for the conversion electron spectrum. Radiations with energies greater than about 30 kev were detected with 1-inch thick, 1½-inch diameter sodium iodide crystals. The crystal windows were $\frac{1}{32}$-inch aluminum. Scintillation pulse spectra from radiations in the 30–460 kev range are plotted in Fig. 2. Three peaks were observed, in agreement with the spectrum from berkelium produced in deuteron bombardment of the curium sample. The broad peak centered at 115 kev is in the region expected for curium K x-rays. The gamma-ray energies are 250 and 380 kev.

TABLE I. Ratios of conversion electrons to K x-rays from the decay of Bk^{245}.

Gamma kev	e_K/x_K	e_{L+M}/x_K
250	0.52	0.13
380	0.009	···

[4] L. B. Magnusson and M. L. Anderson, J. Am. Chem. Soc. **76**, 6207 (1954).

There is no evidence for the 68-kev photon reported by Hulet.[2] The intensity of the shoulder on the low-energy side of the K x-ray peak corresponds to the normal escape peak intensity. A high rate of coincidence was observed for the 115-kev peak with radiations in a 95–150 kev band.

At high detection geometries, pulse summation, in which two photons give simultaneous pulses in the same crystal, becomes significant. The effect is a serious interference with intensity determinations in the present measurements since the sum pulses have heights which are not resolved from those of true single pulses. In attempts to obtain the true relative intensities of the radiations, measurements were made at various geometries and with different thicknesses of absorber. Figure 2 illustrates the use of tantalum absorbers to attenuate the K x-rays. The measurements with absorber attenuation given in Fig. 2 and Table II are not sufficient for the best definition of relative intensities. Pulse summation is eliminated but the solid angle is too large for good elimination of Compton-scattered photons. The apparent intensity of 250-kev photons goes through a minimum with added absorber.

TABLE II. Singles counting.

Photon	Solid angle[a]	Absorber mg/cm² Ta	Detection efficiency[b]	Apparent photons/min	Photons/min corrected
L x-ray	0.188	···	0.18[c]	5460	7340
	0.072	···	0.069[c]	6790	7400
K x-ray	0.174	···	0.14[c]	10 100	10 500
	0.067	···	0.051[c]	11 600	11 800
	0.202	···	0.17	10 800	11 600
	0.089	···	0.076	11 800	12 200
250-kev γ	0.202	···	0.10	3570	2920
		431	0.078	3000	
		847	0.061	3200	
		1287	0.048	3500	
	0.089	···	0.045	3150	2910
380-kev γ	0.202	···	0.054	1070	495
		431	0.048	710	
		847	0.043	560	
		1287	0.039	470	
	0.089	···	0.024	710	455

[a] The solid angle is that subtended at the sample by the face of the NaI crystal.
[b] Detection efficiency is the calculated over-all efficiency which includes the solid angle, crystal-edge effect, effective crystal thickness, full energy peak efficiency and absorber transmission. No attempt was made to correct for inscattering by the tantalum absorbers.
[c] The detector was a $\frac{1}{8}\times 1\frac{1}{4}$ in. crystal with an 18-mil beryllium window. For the remainder of the measurements the detector was a $1\times 1\frac{1}{4}$ in. crystal. Numerical values for efficiencies were taken from the compilation by M. I. Kalkstein and J. M. Hollander [University of California Radiation Laboratory Report No. UCRL-2764, October, 1954 (unpublished)].

The observation of coincidences between the 115-kev peak and radiations in a 95–150 kev band indicated clearly that not all of these radiations were K x-rays from the primary electron capture. The coincidence studies were extended to cover nearly all possible combinations of the electromagnetic radiations. The coincidence counting data are summarized in Table III. Radiation B was selected with a single-channel analyzer. The spectrum coincident with radiation B was displayed on a twenty-channel analyzer. The resolving time, 2τ, was normally 0.08 μsec but was increased to 0.16 μsec when L x-ray coincidence measurements were made.

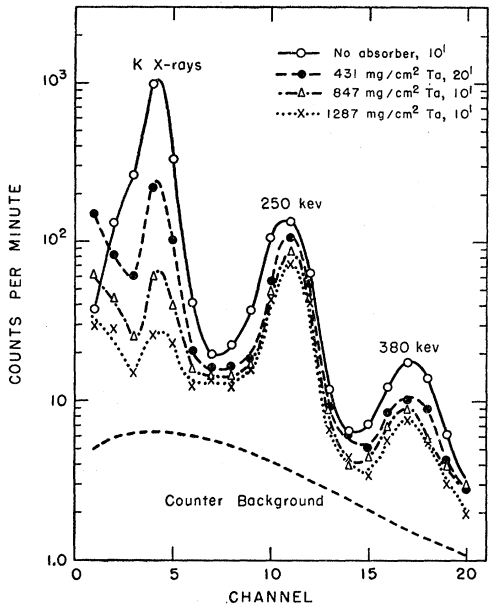

FIG. 2. Electromagnetic spectrum of Bk^{245} detected with 1-inch thick$\times 1\frac{1}{2}$-inch diameter. NaI crystal. (– ○ –) no absorber, 10 min count; (– – ● – –) 431-mg/cm² Ta absorber, 20-min count; (·– △ · –) 847-mg/cm² Ta absorber, 10-min count; (··· × ···) 1287-mg/cm² Ta absorber, 10-min count.

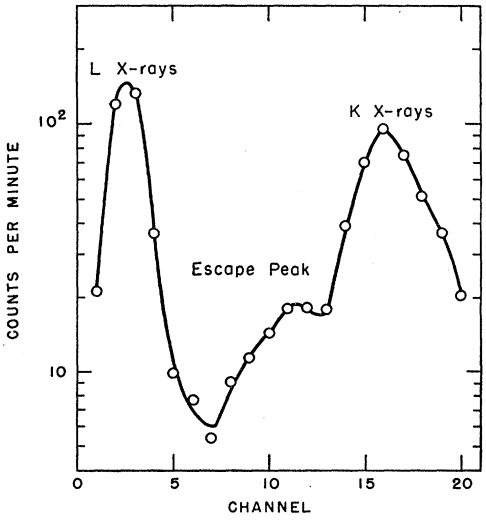

FIG. 3. X-ray spectrum of Bk^{245} detected with $\frac{1}{8}$-inch thick$\times 1\frac{1}{4}$-inch diameter. NaI crystal (18 mil Be window). 10-min count.

TABLE III. Coincidence counting.

Radiation[a] A	Radiation[a] B	Detection efficiency A	Detection efficiency B	Counts/min B	Coincidences/min
L^b	250	0.18	0.049	49±2	3.3 ±0.2
L^b	380	0.18	0.035	5±1	0.39±0.02
K^b	250	0.14	0.049	49±2	4.4 ±0.2
K	250	0.17	0.049	140±8	17.7 ±0.5
K	250	0.17	0.049	58±2	7.1 ±0.2
K^b	380	0.14	0.035	5±1	0.45±0.02
K	97–116	0.17	0.136	535±16	58 ±1
250	97–116	0.10	0.136	535±16	9.9 ±0.4
380	97–116	0.053	0.136	535±16	0.6 ±0.1
380	250	0.053	0.049	58±3	0.13±0.06
250	380	0.061	0.031	5±1	0.09±0.01

[a] No absorber was used in the detection of radiation A except for an 847-mg/cm² Ta absorber in the 250–380 measurement. For the detection of radiation B an 847-mg/cm² Ta absorber was used for all measurements except $K-K$, $250-K$ and $380-K$ (no absorber) and 250–380 (1287 mg/cm² Ta).
[b] These measurements were made with the ⅛-inch NaI crystal. All others were taken with 1-inch crystals.

Delay-time measurement of K x-rays coincident with all radiations greater in energy than 50 kev gave no indication of a lifetime of the excited levels in Cm^{245} greater than 2×10^{-9} sec, the lower limit of the apparatus.

D. Alpha Particles

Alpha-particle activity in the berkelium samples could not be removed by repeated purification. The alpha particle to K x-ray intensity ratio was consistently found to be about 10^{-3}. The most accurate measurement of the ratio of alpha particles to K x-rays gave a value of 0.00084. A single drop of glycolate eluant was dried and ignited on a platinum plate. The alpha particles were counted in an ion chamber. For the K x-ray intensity measurement, the sample was mounted in a collimated sample holder which transmitted 2.60% of the radiation through a ½-inch hole. The radiations were detected by a $\frac{1}{2}\times1\frac{1}{2}$ inch sodium iodide crystal and analyzed with the 20-channel analyzer.

The alpha spectrum of Bk^{245} was measured with the nearly weightless sample prepared from the thenoyltrifluoroacetone chelate extraction. The alpha pulse analyzer was of the type described by Ghiorso, Jaffey, Robinson, and Weissbourd.[5] Three prominent peaks appear in the spectrum (Fig. 4). The averages of the energies of the alpha peaks and their relative intensities for ten such analyses gave the results of Table IV. Although peak shapes are not always well defined by this type instrument, there is some indication of broadening on the high-energy sides of the 5.89- and 6.17-Mev peaks. The effect could be caused by the addition of ionization from conversion electrons to the ionization from the alpha particles.[6]

[5] Ghiorso, Jaffey, Robinson, and Weissbourd, *The Transuranium Elements: Research Papers* (McGraw-Hill Book Company, Inc., New York, 1949), Paper No. 16.8, National Nuclear Energy Series, Plutonium Project Record, Vol. **14B**, Div. IV.
[6] D. W. Engelkemeir and L. B. Magnusson, Rev. Sci. Instr. **26**, 295 (1955).

III. RESULTS AND DISCUSSION

A significant coincidence rate is observed for the 250- and 380-kev radiations (Table III). If there are only two transitions of these energies in series, the coincidence rate, G, is given by Eq. (1)

$$G=\gamma'\epsilon_B(1-a_T'')\epsilon_A, \quad (1)$$

where γ' is the total intensity of 380-kev gamma rays, ϵ subscript is the counting efficiency and $1-a_T''$ is the fraction of the 380-kev gammas which is in series with 250-kev gammas. The factor, $1-a_T''$, is the unconverted fraction of the 250-kev transition, providing no transition exists which is in series with 380 kev but not in series with 250 kev. A rough value of 0.3 for the unconverted fraction of the 250-kev transition is calculable from the relative intensities of conversion electrons and gamma rays (Tables I and II). Substituting the observed values (Table III) for $\gamma'\epsilon_B$ (the 380-kev singles rate) and ϵ_A, the 250-kev counting efficiency, we calculate a coincidence rate of 0.09 in agreement with the observed rate. The 380–250 coincidence rate (0.13 counts/min) should be, and is, equal to the 250–380 rate multiplied by the ratio of the products of the counting efficiencies. Subsequent calculations are based on the evidence that the two transitions are in series and that no transitions bypassing the 250-kev transition are in series with 380 kev.

The conversion electron spectrum shows no evidence for transitions other than those with energies of 250 and ~390 kev. The evidence from the electromagnetic spectra agrees qualitatively if one assumes that all the radiations in the regions of 15 and 115 kev are x-rays.

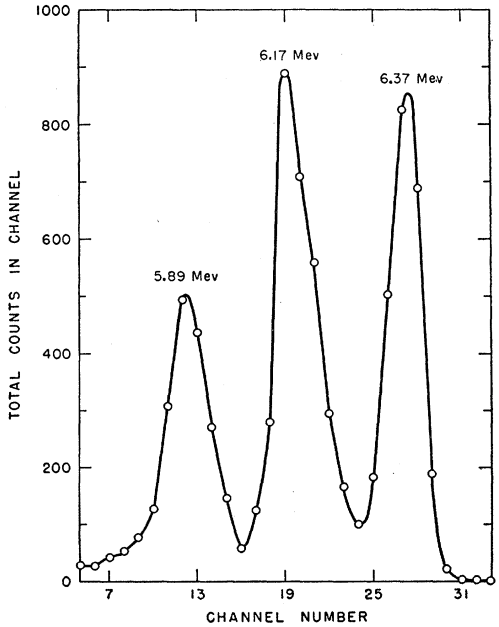

FIG. 4. Alpha-particle spectrum of Bk^{245} measured with ring collimator (⅛-inch high, 1-inch diameter), 1000-min count.

The observed coincidence of 115-kev radiations would be assigned to the coincidence of K electron capture x-rays with K conversion x-rays. Sufficient data are at hand to test the assumption regarding the 115-kev radiation. The rate ratio of $K-K$ coincidences to $K-250$ coincidences will be given by

$$\frac{G_{K-K}}{G_{K-250}}=\frac{2a_K''f_K\epsilon_K}{(1-a_T'')\epsilon_{250}}, \quad (2)$$

where a_K'' is the fraction of the 250-kev transitions converted in the K shell, f_K is the fluorescent yield and the remaining notation has been defined previously. The contribution to the rate ratio by conversion of the 380-kev transition is negligible. Substituting numerical values from Table III with the fluorescent yield equal to 0.98, we calculate a value of 1.76 ± 0.08 for the K conversion coefficients, $a_K''/1-a_T''$, of the 250-kev gamma. The rough value from the relative electron and gamma singles intensity data is 2. The radiation in the region of 115 kev is probably entirely K x-rays. From the singles intensity data (Tables I and II) the preliminary value for the ratio of 250- to 380-kev transitions is about 17. The large 250-kev/380-kev intensity ratio and the apparent absence of other transitions leads to the conclusion that the 250-kev transition is to the ground state of Cm^{245}. The 380-kev transition depopulates a 630-kev level. No other levels or parallel deexcitations of energy greater than 15 kev are present to any appreciable extent. The problem of low-energy radiations and L x-rays will be discussed later.

K electron capture branching to the 630-kev and 250-kev levels was calculated from the K x-ray-gamma coincidence rates given by

$$G_{K-380}=Nb'(1-a_T')\epsilon_B(k'+a_K'')f_K\epsilon_A, \quad (3)$$

and

$$G_{K-250}=N(1-a_T'')\epsilon_B(b''k''+b'k'+b'a_K')f_K\epsilon_A, \quad (4)$$

where b' and b'' are the fractions decaying to the 630- and 250-kev levels, respectively, k is the fraction decaying by K capture, and the remaining symbols retain the previous definitions. The factor $Nb'(1-a_T')\epsilon_B$ in Eq. (3) is the singles counting rate (B, Table III) of the 380-kev gamma. Substituting numerical values with a_K'' equal to 0.55, we find the fraction, k', decaying by K capture to the 630-kev level to be about 0.1. The fraction decaying by K capture to the 250-kev level is 0.75 ± 0.03, the average of the three determinations in Table III.

TABLE IV. Alpha particles from Bk^{245}.

Present work		Hulet *et al.*[a]	
E (Mev)	Relative %	E (Mev)	%
5.89 ± 0.02	26 ± 1	5.90 ± 0.05	27
6.17 ± 0.02	41 ± 2	6.15 ± 0.05	50
6.37 ± 0.02	33 ± 2	6.33 ± 0.05	23

[a] See references 1 and 2.

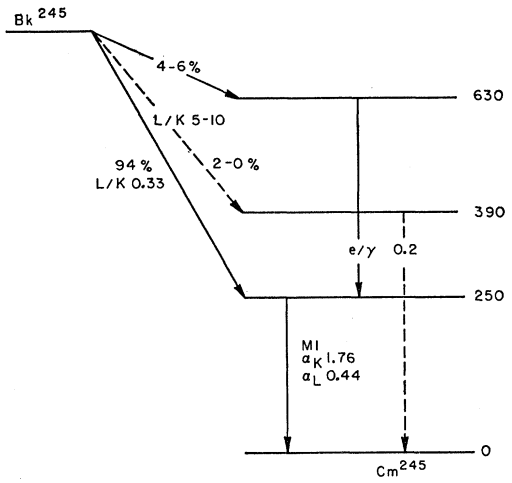

FIG. 5. Electron-capture decay scheme of Bk^{245}.

Since 94% of the electron captures populate the 250-kev level directly, the branching factors a_K'', k', and k'' calculated from the coincidence data do not depend on a highly accurate value for the relative intensities of the 250- and 380-kev gammas. The consistency of the data may be checked, however, by comparing relative intensities calculated from the branching factors with the observed relative singles intensities. The apparent photon intensities in column 5 of Table II were corrected for the pulse summation effect as a function of geometry. The corrected rates are given in the last column of Table II. The average relative K:250:380 intensities from the 1-inch crystal data are 1:0.245:0.040. Assuming that all electron captures to levels above 250 kev populate the 630-kev level, we find the relative intensities from the decay scheme of Fig. 5 to be 1:0.251:0.040 in good agreement with the singles data. Little, if any, K electron capture occurs directly to the ground state.

Further information concerning the decay scheme is contained in the L x-ray data. The considerations given above do not eliminate the possibility of transitions with energies in the L x-ray region. L capture branching to the 630- and 250-kev levels was calculated from the L x-ray gamma coincidence data, and the a and k values derived in the preceding discussion. Corrections were applied for pulse canceling and fluorescent yields.[7]

[7] The number (0.71) of L vacancies per K capture was determined from the theoretical K x-ray intensities of H. W. S. Massey and E. H. S. Burhop [Proc. Cambridge Phil. Soc. **32**, 461 (1936)], extrapolated to $Z=96$. The relative intensity of the K_{β_2} line, which they did not calculate, was assumed to be the same as that for W as measured by W. Duane and W. Stenström, Proc. Natl. Acad. Sci. **6**, 477 (1920). The contribution of Auger transitions was neglected. The L-shell fluorescence yield (0.52) following K capture was obtained from the data of B. B. Kinsey, Can. J. Research **A26**, 404 (1948). The relative excitations of the L levels following a K vacancy were taken as $L_I:L_{II}:L_{III}=0:1:2$. The theoretical relative $L_I:L_{II}:L_{III}$ capture probabilities from the data of Brysk and Rose (reference 15) were combined with the fluorescence yield data of Kinsey to give a total fluorescence yield of 0.48 following either allowed or first-forbidden L capture.

The fractions decaying by L capture to the 630- and 250-kev levels were calculated to be 0.48 and 0.31, respectively. The value of the latter to be expected from the K capture fraction is not more than 0.25. From the decay scheme of Fig. 5 the ratio of L/K x-ray emission is 0.56. The experimental ratio from the values in the last column of Table II is 0.64. These values are the apparent intensities of column four corrected for pulse canceling as a function of geometry. The pulse-canceling corrections are not dependent on accurate values for the fluorescent yields. The fair agreement of the observed coincident and singles L x-ray intensities with the values derived from the K x-ray data is evidence that the prominent modes of decay in the scheme of Fig. 5 are probably correct. There can be no large number of transitions with energies greater than about 8 kev.

It is of interest to note that both the singles L x-ray intensity and the $L-250$ coincidence rate calculated with the values from Fig. 5 would agree very well with the experimental values if the L fluorescent yields were actually ten percent larger than the adopted values of about 0.5. The observed K and L captures do not account for the population of the 630-kev level so one must assume 20–50% M capture.

The K and L conversion coefficients of the 250-kev transition are 1.76 and 0.44, respectively, from the data reported in the present paper. Comparison of the conversion coefficients with theoretical values from Rose, Goertzel, and Perry[8] and Gellman, Griffith, and Stanley[9] indicates that the 250-kev transition has magnetic dipole character. The K conversion coefficient for 250-kev magnetic dipole radiation from the data of Rose *et al.*, is 3.7. The L conversion coefficient should be about 1.0, by extrapolation of the data of Gellman *et al.*

Radiations from levels in Cm^{245} have been detected in other work. From observations of photons associated with the beta decay of Am^{245} Browne *et al.*, have postulated levels in Cm^{245} at 36, 156, 179 and 411 kev.[10] There is no correspondence between these levels and those of Fig. 5 of the present report. The only conversion electrons observed by Browne *et al.*, where K and L electrons from a 255-kev transition with relative intensities about equal to those seen in the Bk^{245} decay. Fields *et al.*[11] have reported photons of ~121 and 260 kev associated with the beta decay of Am^{245} with relative intensities which appear to be about the same as those observed in the singles gamma spectrum by browne *et al.* Assuming that the peak measured as 121 kev is entirely from K x-rays from conversion of the gamma, we calculate a conversion coefficient of 1.6 from the Am^{245} data. The close correspondence in energy and conversion coefficient to the 250-kev transition following the Bk^{245} decay suggests that the same transition is being observed.

Evidence for a 250-kev level in Cm^{245} is found in the alpha particle spectrum of Cf^{249}. Measurements by one of us (L.B.M.) indicate that the ground state and levels at 55, 250, ~290, and 385 kev (90%) are populated by the alpha decay. No alpha decays leading to the 630-kev level deduced from the Bk^{245} data were detected (less than 0.005/disintegration). From the spectrum of gamma rays coincident with Cf^{249} alpha particles, Stephens has concluded that the high-intensity alpha-particle group populates a level at 394 kev.[12] Within the errors of measurement it is likely that the reported values of 385 and 394 kev apply to the same transition.

There are clearly two level separations of nearly the same energy, ~390 kev, in the Cm^{245} level scheme. Some ambiguity remains in the interpretation of the electron capture to levels above 250 kev. It is possible that a small number of the Bk^{245} electron-capture decays populate the level at ~390 kev directly. Within the uncertainties of our measurements the subsequent release of excitation energy would not be distinguishable from that following population of the 630-kev level. The apparent K conversion coefficient of the 380-kev radiation, 0.2, is nowhere near theoretical expectations for either electric or magnetic transitions of small multipole order (theoretical conversion coefficients are 0.02 for $E1$, 0.06 for $E2$, and 1.2 for $M1$).[8] The small value of the apparent conversion coefficient indicates that most of the 380-kev radiation is electric. A branching of the order of two percent of the total disintegrations to the ~390-kev level with $M1$ radiation could account for the conversion electrons. In view of the possible capture to the ~390-kev level, the assignment of K electron capture to the 630-kev level is tenuous.

By assuming that most of the decay goes through the 250-kev level, Hoff and Thompson classified the electron capture decay of Bk^{245} as first forbidden ($\Delta I=0$, 1 yes) from the approximate logft value (6.7).[13] It is of interest to compare the experimental L/K capture ratios with theoretical ratios. The decay energy of Bk^{245} is not well defined, unfortunately, by available data. Since the 630-kev level in Cm^{245} is certainly populated by L capture, the total decay energy is at least 655 kev. This lower limit was used with the equation for transition probabilities and the wave function values given by Brysk and Rose for first forbidden ($\Delta I=0$, 1 yes) electron capture to calculate the probabilities for capture to the 250-kev level.[14] The relative K and L capture probabilities associated with

[8] Rose, Goertzel, and Perry, Oak Ridge National Laboratory Report ORNL-1023 (1951) (unpublished).
[9] Gellman, Griffith, and Stanley, Phys. Rev. **85**, 944 (1952).
[10] Browne, Hoffman, Crane, Balagna, Higgins, Barnes, Hoff, Smith, Mize, and Bunker, J. Inorg. Nuclear Chem. **1**, 254 (1955).
[11] Fields, Studier, Friedman, Diamond, Sjoblom, and Sellers, J. Inorg. Nuclear Chem. **1**, 262 (1955).
[12] F. S. Stephens, Jr., thesis, University of California Radiation Laboratory Report UCRL 2970, June, 1955 (unpublished).
[13] R. W. Hoff and S. G. Thompson, Phys. Rev. **96**, 1350 (1954).
[14] H. Brysk and M. E. Rose, Oak Ridge National Laboratory Report ORNL-1830, January, 1955 (unpublished).

each matrix coefficient are listed in Table V. The matrix coefficients are unknown. With the exception of the terms in the sixth and eighth rows of the table, however, the L/K capture ratio for each term is nearly the same. Providing no large negative coefficients occur, the actual values of the matrix coefficients can have little effect on the L/K capture probability ratio. With the gross assumption that all the coefficients are positive and of the same magnitude, the ratio of the sums of the relative L and K probabilities is 0.38. The contributions from the sixth and eighth row terms are negligible. The capture probabilities for first forbidden unique decay ($\Delta I=2$ yes) are given by the entries in the sixth row of Table V ($L/K=0.91$). All the other terms make no contribution to first-forbidden unique transitions. The experimental L/K ratio of 0.33 suggests that the total decay energy is somewhat larger than 655 kev.

The theoretical L/K ratio for an allowed transition to the 250-kev level is also about 0.38, calculated with the lower limit of 655 kev for the Bk^{245} decay energy. As pointed out by Brysk and Rose, the agreement is a consequence of the equality of the ratios of the "large" and "small" components of the Dirac radial wave functions for the L_{I} and K shells. The $L_{\mathrm{II}}/L_{\mathrm{I}}$ ratio is insensitive to the order of forbiddenness and L_{III} capture is negligible for allowed and first forbidden ($\Delta I=0$, 1 yes) decay. The L/K capture ratio calculated for the allowed type of transition appears to be a good approximation for the L/K ratio for first forbidden ($\Delta I=0$, 1 yes).

If K capture occurs to the 630-kev level, the L/K ratio being greater than 4 from the present measurements, we calculate an upper limit to the total decay energy of 790 kev. This upper limit corresponds to a theoretical L/K ratio of 0.30 for capture to the 250-kev level. The experimental L/K ratio of 0.33 suggests that K capture to the 630-kev level is energetically impossible, although the evidence can be given little weighting from consideration of the experimental and theoretical uncertainties. In summary, the experimental L/K ratio for capture to the 250-kev level is consistent with theoretical expectations for first forbidden decay ($\Delta I=0$, 1 yes). The problems of decay to higher levels and the decay energy of Bk^{245} require more accurate data.

TABLE V. Contributions of the various matrix elements to the relative K and L capture probabilities for Bk^{245} with 655-kev total decay energy (lower limit).

Matrix coefficient	K	L_{I}	L_{II}	L_{III}	L/K
$G_S{}^2K_1$	108	36	6	···	0.39
$G_T{}^2I_0(1,\boldsymbol{\sigma})$	1358	457	74	0	0.39
$G_T{}^2I_1(1,\boldsymbol{\sigma})$	0.40	0.14	0.02	···	0.40
$G_T{}^2I_1(0,\boldsymbol{\sigma}\times\mathbf{p}/M)$	5.3	1.8	0.27	0	0.39
$G_T{}^2I_1(0,1;\boldsymbol{\sigma},\boldsymbol{\sigma}\times\mathbf{p}/M)$	48	21	−3	0	0.38
$G_T{}^2I_2(1,\boldsymbol{\sigma})$	0.128	0.087	0.012	0.017	0.91
$-G_SG_TJ_1(1,\boldsymbol{\sigma})$	2420	776	116	···	0.37
$-G_SG_TJ_1(0,\boldsymbol{\sigma}\times\mathbf{p}/M)$	51	26	−2.5	0	0.46

From the relative intensity of alpha particles (Sec. II. D) and the value of 1.27 for the number of K vacancies per disintegration the half-life for decay by alpha-particle emission is 13 years in good agreement with the value of 14 years derived by Hulet, Thompson, Ghiorso, and Street.[1] Differences in the alpha-particle energies of Bk^{245} suggest levels in Am^{241} at ~200 and 480 kev. Glass has assigned a 470-kev gamma ray following the electron-capture decay of Cm^{241} to a transition to ground.[15]

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[15] R. A. Glass, thesis, University of California Radiation Laboratory Report UCRL-2560, 1954 (unpublished).