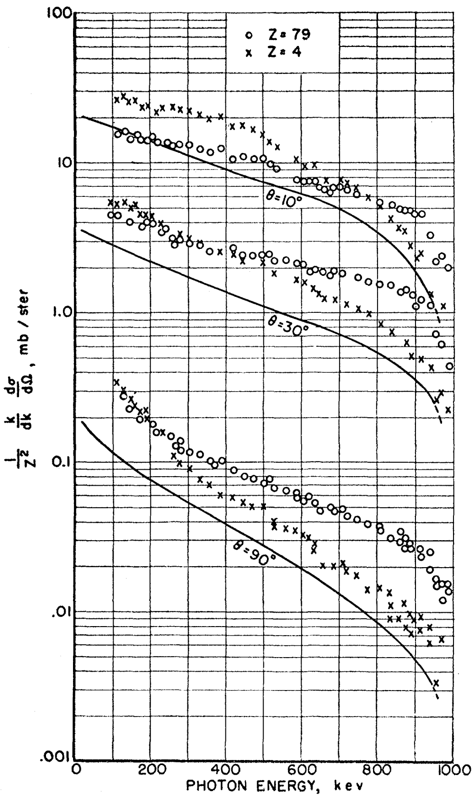

FIG. 1. Differential cross section for 1-Mev bremsstrahlung at photon energies k and angles θ, of 10°, 30°, and 90°. The fractional standard deviations of the experimental points due to counting rate statistics are less than 10 percent for points below 800 kev, less than 20 percent for points below 900 kev, and less than 30 percent for points below 1000 kev. The theoretical cross sections are shown by the solid curves which were obtained from the results of Sauter (see reference 5) and Gluckstern and Hull (see reference 5).

The radiation passed to the spectrometer through a 15-mil Al window in the evacuated target chamber. Electrons traveling in the direction of this window were deflected by an electron trap employing a permanent magnet. To account for the contribution of the radiation arising from normal background and from electron scattering in the chamber, measurements were made with the target foil in and out of the electron beam.

The spectrometer consisted of a $\frac{3}{8}$-inch diameter 12-inch long collimator, a 5-inch diameter 4-inch long NaI(Tl) crystal, a type K1198 Dumont 5-inch diameter photomultiplier tube, and lead shielding extending 12 inches in front, 3 inches on the sides, and $\frac{1}{2}$ inch in the back of the crystal housing. The pulse-height distribution produced by incident radiation was measured with a 12-channel analyzer having approximately 15-kilovolt window widths which were calibrated during runs with a motor-driven sliding pulser. The pulse-height response of this spectrometer to monoenergetic photons appears as a line shape with a low energy tail[3] which replaces the prominent Compton escape peak found with small crystals. This response was characterized by a matrix whose indices corresponded to pulse height and photon energy. Thus, a matrix element specified the counting rate at a given pulse height for photons of a given flux density and of a given energy. These matrix elements were found by interpolation between the response curves measured for the photons from sources of Co^{60}(1.17 Mev, 1.33 Mev),[4] Cs^{137} (0.662 Mev),[4] Hg^{203} (0.279 Mev),[4] and Cd^{109} (0.087 Mev).[4] The matrix determined a set of simultaneous linear equations relating any pulse-height distribution to the corresponding input photon spectrum. In the present case, the bremsstrahlung yielded pulse-height distributions which fell off rapidly with increasing pulse height so that a line-by-line solution of the simultaneous equations was permissible with the aid of a simple perturbation type calculation.

Measurements of the bremsstrahlung spectra were made at angles of 10°, 30°, and 90°, and yielded values of the differential cross section shown in Fig. 1. For comparison, the differential cross section integrated over electron angle, as given by Sauter[5] on the basis of the Born approximation, is shown by the solid lines. It is seen that (a) the prediction of the large intensity variation with angle θ (two orders of magnitude between 10° and 90°) is confirmed, (b) although the measured integrated intensity goes roughly as Z^2, the measured spectral shape is Z dependent, and (c) the theoretical curves appear to underestimate the measured cross sections.[6] Measurements at other angles and materials, and for 500-kev electrons are now in progress.

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Correlation of Spontaneous Fission Half-Lives

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EMPIRICAL correlations which can be used in predicting the properties of undiscovered elements and isotopes are of great practical value. Many such

relationships involving alpha-disintegration and spontaneous fission rates have been published.[1–5] Kramish[4] correlated the competition between alpha decay and spontaneous fission with the fissionability parameter Z^2/A. As a measure of the above competition,[6] he used the ratio of the spontaneous fission half-life to the alpha-disintegration half-life, R, and showed a relationship between consecutive alpha-decay products.

Recently, alpha disintegration and spontaneous fission half-lives of a number of newly discovered nuclides have been measured (data and references given in Table I). We have observed that linear lines connecting (on semi-logarithmic paper, see Fig. 1) even-even

TABLE I. Alpha-disintegration and spontaneous fission half-lives.

Isotope	$T_{\frac{1}{2}}(\alpha)$ (yr)	Ref.	$T_{\frac{1}{2}}$(s.f.) (yr)	Ref.	$T_{\frac{1}{2}}$(s.f.)/$T_{\frac{1}{2}}(\alpha)$
Th^{230}	8.0×10^4	a	$\geq1.5\times10^{17}$	i	$\geq1.9\times10^{12}$
Th^{232}	1.39×10^{10}	a	1.4×10^{18}	i	1.0×10^8
Pa^{231}	3.4×10^4	a	$\geq10^{16}$	i	$\geq2.9\times10^{11}$
U^{232}	74	b	$\geq8\times10^{12}$	i	$\geq1.1\times10^{11}$
U^{233}	1.6×10^5	a	$\geq3\times10^{17}$	i	$\geq1.9\times10^{12}$
U^{234}	2.5×10^5	a	1.6×10^{16}	i	6.4×10^{10}
U^{235}	7.1×10^8	a	1.8×10^{17}	i	2.5×10^8
U^{236}	2.4×10^7	a	2×10^{16}	i	8.3×10^8
U^{238}	4.5×10^9	a	8.0×10^{15}	i	1.8×10^6
Np^{237}	2.2×10^6	a	$\geq4\times10^{16}$	i	$\geq1.8\times10^{10}$
Pu^{236}	2.7	a	3.5×10^9	i	1.3×10^9
Pu^{238}	90	a	4.9×10^{10}	i	5.4×10^8
Pu^{239}	2.44×10^4	a	5.5×10^{15}	i	2.3×10^{11}
Pu^{240}	6.6×10^3	a	1.2×10^{11}	i	1.8×10^7
Pu^{242}	3.8×10^5	c	6.7×10^{10}	i	1.8×10^5
Am^{241}	4.7×10^2	a	$\geq1.4\times10^{13}$	i	$\geq3.0\times10^{10}$
Cm^{240}	7.3×10^{-2}	a	1.9×10^6	i	2.6×10^7
Cm^{242}	0.445	a	7.2×10^6	i	1.6×10^7
Cm^{244}	18.4	d	1.4×10^7	i	7.6×10^5
Cm^{246}	4×10^3	d	...	...	...
Bk^{249}	...	...	$\geq2\times10^8$	e	...
Cf^{246}	4.1×10^{-3}	a	2.1×10^3	i	5.1×10^5
Cf^{248}	0.56	a	7×10^3	i	1.3×10^4
Cf^{249}	470	e,f	$\geq5\times10^6$	e	$\geq1.2\times10^4$
Cf^{250}	10	e,f	1.5×10^4	e,f,j	1.5×10^3
Cf^{252}	2.2	e,f	66	e,f	3.0×10^1
99^{253}	5.3×10^{-2}	g,h	$\geq3\times10^5$	g	$\geq5.7\times10^6$
99^{254}	...	...	≥10	g	...
100^{254}	3.8×10^{-4}	g,h	0.60	g,h	1.6×10^3

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nuclides differing by two Z units and six A units give better extrapolated values of R than linear lines connecting alpha-decay products. On a particular line ($\Delta Z=2$, $\Delta A=6$; solid lines), the values of R decrease with increasing values of Z^2/A. In general alpha-disintegration half-lives of even-even isotopes of a given element beyond the double closed shell at lead decrease with increasing Z^2/A values (there is a reversal[7,8] of this trend at Cf^{252}), whereas the spontaneous fission half-lives of even-even isotopes go through a maximum[5] with increasing Z^2/A values. However, it is interesting

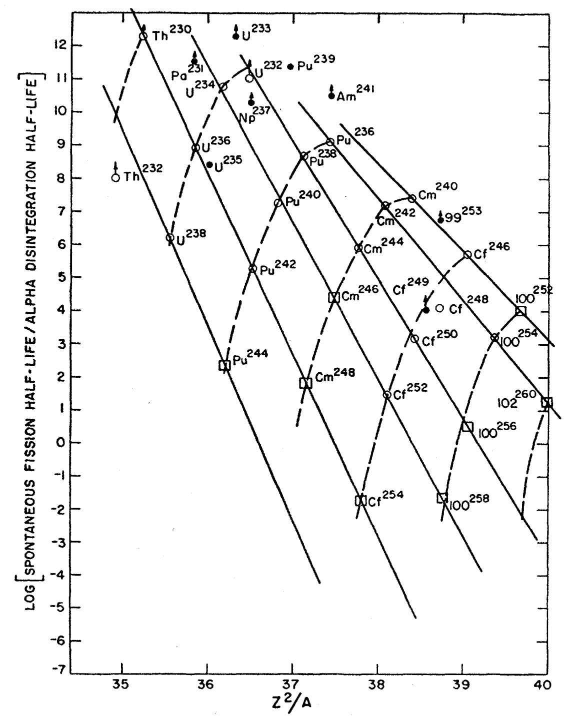

FIG. 1. Plot of the ratios of the spontaneous fission half-lives to the alpha-disintegration half-lives *vs.* the fissionability parameter Z^2/A. The solid lines connect even-even nuclides with $\Delta Z=2$ and $\Delta A=6$. Dashed lines connect even-even isotopes of a given element. Open circles ○, R values of even-even nuclides; solid circles ●, R values of odd nuclides; and squares □, predicted R values.

to note that R values increase with increasing Z^2/A values for the even-even isotopes of a given element (dashed lines in Fig. 1).

It can be seen from Fig. 1 that the value of R for Th^{232} appears low indicating that the measured spontaneous fission half-life may be a lower limit. Cf^{252} with an R value of 30 exhibits the largest spontaneous fission decay branching measured to date. The predicted R value for Cf^{254} from Fig. 1 is 0.018, which means that Cf^{254} would decay mainly by spontaneous fission.

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