considerations. If one assumes that the spacing between resonances is of the same order of magnitude as the energy of the first resonance, then In^{115} would be expected to have a spacing between resonances of a few electron volts.

We have recently remeasured the indium cross section to investigate the apparent discrepancy in the density of resonances. The measurements were made with the Brookhaven crystal spectrometer,[6] which uses a beryllium crystal for the monochromator. Beryllium gives relatively good intensity and resolution up to about 50 ev. The total cross section for normal indium obtained with this instrument is shown in Fig. 1.

It is possible to use small samples with the spectrometer; hence enriched isotopes[7] of indium could be used to identify the resonances. The transmission curves for normal and enriched samples are shown in Fig. 2. It should be noted that all three of the resonances previously reported belong to In^{115}. Several additional resonances have been observed in both isotopes. The results are summarized in Table I along with the corresponding resolution width for each resonance.

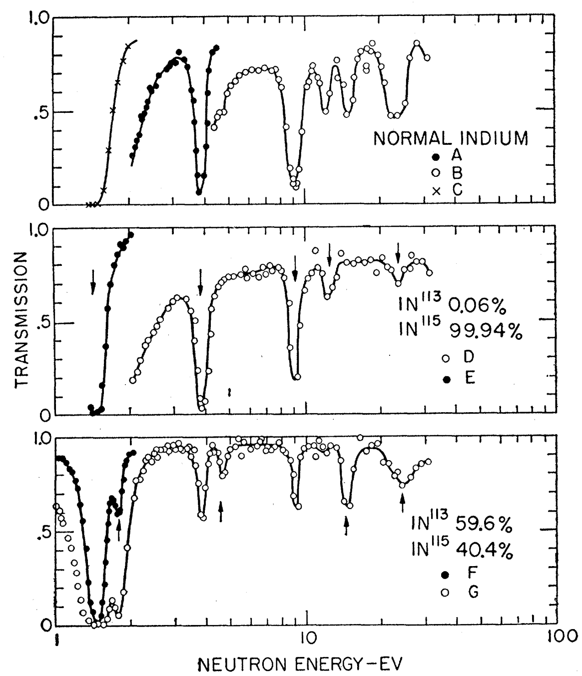

FIG. 2. Transmission for normal indium and two enriched samples. The dip at 25 ev in In^{113} is too broad to be a single resonance. Sample thicknesses are as follows: $A=1.873$, $B=8.003$, $C=0.189$, $D=2.20$, $E=0.14$, $F=0.14$, $G=0.61$ g/cm².

It appears that the spacing between resonances is about 6 ev in each of the isotopes. The strength of the resonances in any one isotope varies considerably. For example, in In^{115} the resonances at 1.458 and 3.86 ev have relative strengths $(\sigma_0\Gamma^2)_{1.46}/(\sigma_0\Gamma^2)_{3.86}\approx 45$. If we assume that Γ_γ is the same order of magnitude for both resonances, then after correcting for the ratio of λ_0^2 one obtains the approximate result $(g\Gamma_n)_{1.458}/(g\Gamma_n)_{3.86}\approx 17$. If it is assumed that only *s* neutrons are effective in producing the 3.86-ev resonance, it is impossible to explain such a large difference in the magnitude of $g\Gamma_n$ for the two resonances on the basis of current resonance theory.

TABLE I. Neutron resonances in indium isotopes. The term ΔE is the full width at half-maximum of the resolution triangle of the instrument.

E_0 (ev)	Isotope	ΔE (ev)
1.458 ±0.003	115	0.041
1.80 ±0.03	113	0.056
3.86 ±0.02	115	0.176
4.69 ±0.03	113	0.235
9.16 ±0.05	115	0.643
12.1 ±0.1	115	0.98
14.8 ±0.2	113	1.33
22–26 (two or more)	113	~2.8
23.5 ±1.0	115	2.6

A more detailed analysis of the resonances is being prepared and will be submitted for publication in the near future.

† Research carried out under the auspices of the AEC.
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6 A full description of this instrument will be submitted for publication in the near future.
7 The enriched isotopes were obtained on loan from the Isotope Research and Production Division of the AEC.

Isomers in Tellurium 133†

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OBSERVED discrepancies in the fission yields of the members of mass-chain 133 suggested the existence of an isomer of Te^{133}.[1] On theoretical grounds, Goldhaber[2] predicted that the 66-min Te^{133} is the upper member of an isomeric pair and that the ground state for Te^{133} probably has a short half-life. This phenomenon may be responsible for the apparent discrepancy in the cumulative fission yields.

In irradiated UO_3 tellurium fission products were first removed and tellurium then isolated from the decay of 4.4-min Sb^{133}. The last tellurium samples show a perceptible growth of a short-lived daughter in the 63-min decay curve. The half-life of the daughter is found to be about 2 min.

In studies of the chemical states of tellurium formed in fission, Williams[3] showed that if the parent isomer is held in acid solution in the valence state +6, most of the daughter will be formed in the lower valence state +4. A fast daughter separation by selective reduction with H_2S was made from the 63-min Te prepared in the +6 state. The daughter fraction decayed with a prominent component of half-life about 2 min. The parent showed a half-life of 63 min.[4]

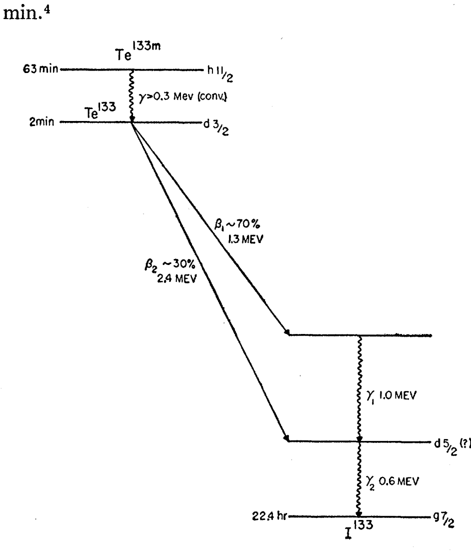

FIG. 1. Tentative decay scheme $Te^{133m}\rightarrow Te^{133}\rightarrow I^{133}$.

Aluminum absorption curves of pure 63-min Te^{133m} in equilibrium with 2-min Te^{133} gave, when analyzed by the Feather method: 1.3-Mev β, 2.4-Mev β and probably a high energy component but in very low abundance. Electrons of about 0.3 Mev energy were also found, showing the existence of converted gammas of energy >0.3 Mev.

Lead absorption curves showed γ-rays with energies 0.3 Mev; 0.6 Mev, and 1.0 Mev. A tentative decay scheme is given in Fig. 1.

The energy >0.3 Mev for the transition 63-min Te^{133m}/2-min Te^{133} is somewhat lower than that predicted by Goldhaber, ~0.4 Mev. The value 0.3 Mev was determined by absorption measurements, and the precision is not very high in this case because of the presence of the β-rays.

In order to make a more precise determination, experiments were done together with M. Goldhaber at the Brookhaven National Laboratory. In order to get higher activities the reactor was used, and carefully purified Te^{133m} in equilibrium with 2-min Te^{133} was studied using a scintillation spectrometer. Preliminary experiments showed that the decay is rather complex, but a converted gamma of about 0.4 Mev energy is probably there. This work will therefore be continued.

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Spontaneous Fission of U^{234}, Pu^{236}, Cm^{240}, and Cm^{244}†

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In a recent communication commenting on the mechanism of fission we called attention to the simple exponential dependence of spontaneous fission rate on Z^2/A and to the effect of an odd nucleon in slowing the fission process.[1] Since it is of interest to test further the simple correlation of the spontaneous fission rate for even-even nuclides with Z^2/A, a further number of such rates have been determined.

The spontaneous fission rates were measured by placing the chemically purified samples on one electrode of a parallel plate ionization chamber, filled with a mixture of argon and carbon dioxide, which was connected with an amplifier followed by a register and a stylus recorder. The results are summarized in Table I. The U^{234} was a sample of high isotopic purity obtained by the electromagnetic concentration process, the Pu^{236} was prepared by bombarding highly enriched U^{235} with 18-Mev deuterons according to the reactions

$$U^{235}(d, n)Np^{236} \xrightarrow{\beta^-} Pu^{236},$$

the Cm^{240} came from the bombardment of Pu^{239} with 38-Mev helium ions according to the reaction $Pu^{239}(\alpha, 3n)Cm^{240}$, and the Cm^{244} came from the pile neutron bombardment of Am^{243} (containing Am^{241}) by the reactions

$$Am^{243}(n, \gamma)Am^{244} \xrightarrow{\beta^-} Cm^{244}.$$

By the nature of their methods of production, the Cm^{240} and Cm^{244} contained some Cm^{242} whose spontaneous fission had to be subtracted from the total rate in each case. The Cm^{240} also contained some Cm^{241}, but since the fission rate seemed to decay with the half-life of Cm^{240}, the contribution of the Cm^{241} must have been small. This observation on Cm^{241} would agree with the lower rate expected for nuclides having odd nucleons. The result for U^{234} is consistent with the earlier observation of Segrè,[2] who reported an upper limit of 30 spontaneous fissions/gram-hour.

TABLE I.[a] Spontaneous fission rates of U^{234}, Pu^{236}, Cm^{242}, and Cm^{244}.

Nuclide	Fissions/g-hr	"Half-life" (years)
U^{234}	13 ± 6	$2\pm1 \times10^{16}$
Pu^{236}	$5.8\pm2 \times10^{7}$	$3.5\pm1 \times10^{9}$
Cm^{240}	$1.0\pm0.2 \times10^{11}$	$1.9\pm0.4 \times10^{6}$
Cm^{244}	$1.4\pm0.2 \times10^{10}$	$1.4\pm0.2 \times10^{7}$

[a] The errors indicated are statistical only and do not include any estimate for possible systematic errors.

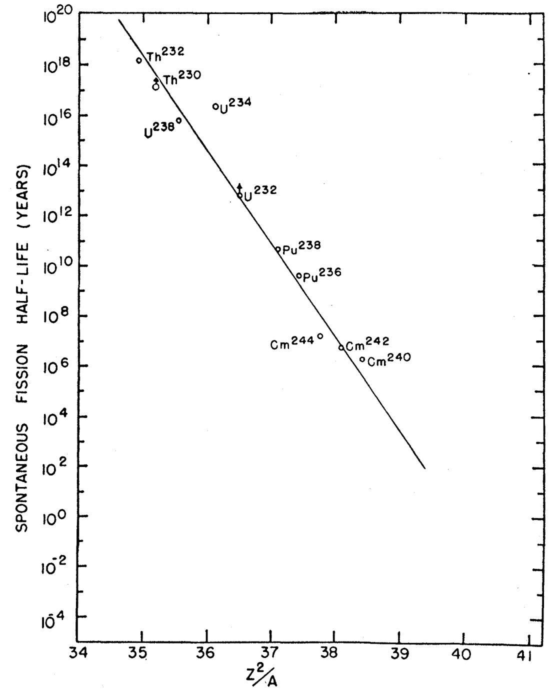

FIG. 1. Plot of spontaneous fission rates of even-even nuclides (♂ signifies lower limit to half-life).

These data are included in Fig. 1, which is otherwise identical with the plot in the previous report[1] (where references are given), with the exception that odd-nucleon nuclides, which apparently all fall above the line, are not included. As can be seen, the new even-even nuclides fit in fairly well with the correlation. However, some even-even nuclides such as U^{234}, and possibly also U^{232} and Th^{230}, exhibit substantial deviations in the direction of slower rates. It is apparent that more data are needed in order to establish the pattern for even-even nuclides in detail. Nevertheless, it can be definitely stated that the spontaneous fission rates for even-even nuclides seem to define a certain limiting rate, and it seems especially significant that the extrapolation of the line (in Fig. 1) representing this rate to the region of instantaneous rate (that is, half-life of the order of 10^{-20} second) gives a value of about 47 for Z^2/A, which corresponds with the predicted limiting value for Z^2/A.

Similar considerations in regard to spontaneous fission rates have recently been published by Whitehouse and Galbraith.[3]