rying out the angle integrations, we obtain

$$J=\sum_{n} C_{\lambda,\Lambda,\gamma,\Gamma} f_{\lambda,\Lambda,\gamma,\Gamma,n}(R,\theta,\Theta,\beta)\cos\gamma\varphi\cos\Gamma\Phi$$

$$\times\left\{\int_{u_L}^{b}(u')^2du'\int_{v_L}^{\infty}(v')^2dv'\cos^{\lambda}\beta'\sin^{\Lambda}\beta'\right.$$

$$\times F(-n,\lambda+\Lambda+n+2;\Lambda+\tfrac{3}{2};\sin^2\beta')$$

$$\times\frac{J_{\lambda+\Lambda+2n+2}[k(u'^2+v'^2)^{\frac{1}{2}}]}{(u')^2+(v')^2}\frac{J_{\lambda+\frac{1}{2}}(K_\lambda u')}{u'^{\frac{1}{2}}}$$

$$\left.\times\frac{H_{\Lambda+\frac{1}{2}}^{(1)}[v'(k^2+k_0^2-K_\lambda^2)^{\frac{1}{2}}]}{v'^{\frac{1}{2}}}\right\},\quad\text{(A-7)}$$

(where $u'=R'\sin\beta'$, $v'=R'\cos\beta'$, and the $C_{\lambda,\Lambda,\gamma,\Gamma}$ are coefficients arising from the angle integrations) with u_L and v_L determined by $u_L^2+v_L^2=R_0^2$, where R_0 is the reaction zone boundary.

We now show that each of the above integrals can be restricted to a region in (u',v')-space which is no greater than several wave-guide mode wavelengths from the origin, with an error that damps exponentially in the parameter "cutoff$\times(k^2+k_0^2-K_\lambda^2)^{\frac{1}{2}}$." Since the u' integration extends only to $u'=b$, we need merely show that the v' integral can be cut off at several guide mode wavelengths, say at $v'=v_0$. We now investigate the behavior of the v' integral for $v'>v_0$, where the Hankel function may be expressed by its asymptotic form and the hypergeometric function is equal to $1+O(b^2/v_0^2)$. This integral can also be expressed as an integral over a finite region with an exponentially damped remainder. This can be seen by deforming the path of integration (from v_0 to ∞ on the real axis) to a new path running from v_0 to iv_0 (say along an arc of the circle $|v'|=v_0$), then from iv_0 to $i\infty$ along the imaginary axis, and finally along an infinite arc to $v'=\infty$. (If we had taken a mode having $H^{(2)}$ rather than $H^{(1)}$, the path would have been deformed into the lower half plane, rather than the upper.) The infinite arc contributes nothing because the integrand vanishes there. The integral from iv_0 to $i\infty$ is clearly exponentially damped [i.e., it has as a factor

$$\exp[-(v_0(k^2+k_0^2-K_\lambda^2)^{\frac{1}{2}}-k(v_0^2-b^2)^{\frac{1}{2}})],$$

which damps for energies sufficiencly close to threshold that $k<(k^2+k_0^2-K_\lambda^2)^{\frac{1}{2}}/(1-b^2/v_0^2)^{\frac{1}{2}}$]. Finally, the integral from v_0 to iv_0 extends over a finite region, and can be lumped with the integral from v_L to v_0 to yield the desired transform of J into an integral over a finite region.

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Mass Distribution in Fission of U^{235} by Resonance Neutrons*

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Radiochemical analyses of samples of U^{235} irradiated with monoenergetic neutrons at 1.1, 3.1, and 9.0 ev indicated that the fission yield of Ag^{111}, Cd^{115}, and Sb^{127} relative to the yield of Sr^{89} does not change from that produced by thermal neutrons.

INVESTIGATIONS of the variation of fission yield with mass have been made under a wide variety of experimental conditions, but these studies have not included fission induced by resonance neutrons of well-defined energy. A determination of the relative probabilities of symmetric and asymmetric modes of fission at specific resonances might give further insight into the nature of the fission process and the properties of the states of the compound nucleus corresponding to the resonances. In particular, Bohr[1] has presented qualitative considerations relating the relative probabilities of symmetric and asymmetric fission modes to the spin and parity of the state of the compound nucleus.

Measurements of ν, the number of neutrons per fission, have indicated that this quantity remains essentially constant for all resonances.[2] However, it was felt that a study of the features of the curve of yield *vs* mass would provide a more sensitive measure of possible differences in fission modes at different resonances.

Samples of U^{235} metal (about 90 g each, 1 cm$\times$1 cm $\times$10 cm) were irradiated with neutrons from a crystal

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[1] A. Bohr, *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955* (United Nations, New York, 1956), Vol. 2, p. 151.

[2] Auclair, Landon, and Jacob, Compt. rend. **241**, 1935 (1955); Zimmerman, Palevsky, and Hughes, Bull. Am. Phys. Soc. Ser. II, **1**, 8 (1956); Leonard, Seppi, and Friesen, Bull. Am. Phys. Soc. Ser. II, **1**, 8 (1956); Bollinger, Coté, Hubert, Leblanc, and Thomas, Bull. Am. Phys. Soc. Ser. II, **1**, 165 (1956).

spectrometer in the arrangement shown in Fig. 1. Neutrons of 1.1, 3.1, and 9.0 ev were used in a series of irradiations, each lasting for about three days. The beam used in these irradiations was about 11 cm high at the sample position and contained about 10^4 neutrons per second in the energy region of interest. The resolution of the instrument (full width at half-maximum) was about 5.3% at 1 ev and 15% at 9 ev. Background irradiations were performed by turning the crystal about 2° from the direction satisfying the Bragg reflection conditions.

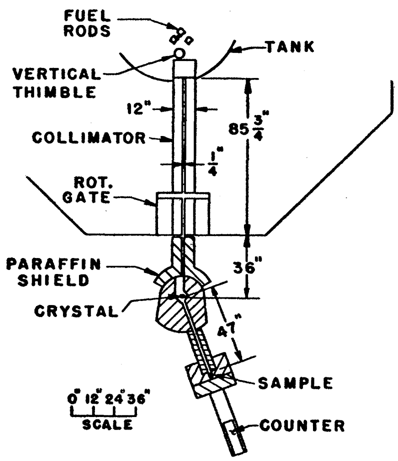

FIG. 1. Horizontal cross section of the crystal spectrometer for neutrons at the Argonne Research Reactor, CP-5. The beam is monochrotized by reflection from the vertical, (110) planes of a Be crystal approximately 1.5 cm×1.5 cm ×7 cm high.

Standard radiochemical procedures were carried out on the irradiated samples for Sr^{89}, Ag^{111}, Cd^{115}, and Sb^{127}. Comparisons of the counting rates observed were made with samples of the same nuclides isolated from samples of normal uranium irradiated by slow (pile) neutrons, and mounted and counted in an identical manner. Calculations of the fission yields could thus be made on a relative basis, using the known yields for fission of U^{235} by slow neutrons, and avoiding corrections for geometry, scattering, absorption, etc. Initial counting rates of the order of 5 counts/min were observed for Cd^{115}. This was sufficient to characterize the radiations by decay measurements. All samples were counted in an anticoincidence shielded counter having a background of about 2 counts/min. The results are summarized in Table I.

TABLE I. Fission yields in fission of U^{235} by resonance neutrons from 1 to 10 ev.

Nuclide	1.1 ev	3.1 ev	9.5 ev	Pile
Sr^{89}	4.8%[a]	4.8%[a]	4.8%[a]	4.8%[a]
Ag^{111}	0.020%	0.019%	0.018%	0.018%
Cd^{115}	0.013%	0.008%	0.010%	0.011%
Sb^{127}	0.11 %	...	...	0.10%

[a] Assumed yield; others calculated relative to Sr^{89}.

The preliminary data indicate no differences in the relative probabilities of asymmetric modes (represented by Sr^{89}) and near-symmetric modes (represented by Ag^{111}, Cd^{115}, and Sb^{127}). The accuracy of the measurements of fission yield is estimated as ±20%. The extremely low counting rates for Cd^{115} and the rather high background effect (varying from about 20% at 1.1 ev to about 50% at 9.5 ev) would preclude any observation of a real decrease in the probability of symmetric fission modes. However, the data can certainly be taken to show that no significant increase in these modes occurs at the resonances investigated. Further studies are planned with increased sensitivity and reduced background so that regions between resonances may be investigated also.