greater than that of the K capture branch followed by the 109.1 transition. It is known from the coincidence data that the 216.1- and 325.1-kev radiations have half-lives shorter than about 10^{-6} sec, and the half-life of the 109.1 must be of the same order of magnitude as that of the 325.1. A comparison of the measured K/L ratios with the empirical curves[5] and of the information on conversion coefficients with the theoretical values[6] indicates that the 109.1-, 216.1-, and 325.1-kev transitions are, respectively, $E2$, $M1$, and $E2$. The 570-kev gamma probably follows another weak K capture branch, but its terminal level is uncertain. A nuclear level scheme for Tc^{97} consistent with the above information is shown in Fig. 3.

Note added in proof.—A consideration of the expected half-lives for the 9-, 90.2-, and 99.2-kev transitions indicates the possibility of interchanging the order of the 9- and 90.2-kev gammas. The 9-kev transition would then be interpreted as $E3$ and the 90.2-kev transition as of lower multipole order.

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Distribution of the Number of Prompt Neutrons from the Spontaneous Fission of Pu^{240}†

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A measurement of the distribution of the number of neutrons per fission of Pu^{240} yielded the following probabilities, P_m, for 0,1,2, etc. neutrons: $P_0=0.062$, $P_1=0.198$, $P_2=0.374$, $P_3=0.228$, $P_4=0.114$, $P_5=0.027$, $P_6=0.000$. The measurement was made with a liquid scintillation counter.

THE distribution in the number of prompt neutrons emitted in the spontaneous fission of Pu^{140} has been investigated by means of a large liquid scintillator of high efficiency for the detection of neutrons.

The neutron detector was similar to the one described by Cowan *et al.*,[1] where neutrons are detected by cadmium capture gamma-ray pulses in the liquid scintillator. The detector consisted of a cylindrical tank 16 inches high and 16 inches in diameter with 32 DuMont 1177 photomultiplier tubes. The detector was filled with toluene loaded to 4 g per liter with *p*-terphenyl. It used a wavelength shifter of *POPOP*[2] and was loaded with cadmium in the form of cadmium octoate[3] to a concentration of 0.0025 cadmium atoms per hydrogen atom.

A 45-microgram Pu^{240} sample was placed on a foil in a small parallel plate fission chamber at the center of the scintillator tank. A fission pulse from the fission chamber was used to initiate the process of recording the liquid scintillator output. Figure 1 is a block diagram of the experimental arrangement. All fission chamber pulses above an appropriate bias level triggered the control circuit. The control circuit then triggered a 40-microsecond oscilloscope sweep and wound the camera. A provision for preventing an oscilloscope sweep during the 10 second camera wind period was included in the control circuit. The output of the liquid scintillator was delayed and fed to the oscilloscope for display during the 40 microsecond sweep. The delay in the liquid scintillator channel was required to insure the display of the prompt fission gamma and neutron pulses from the scintillator.

A pulse-height analysis was made of the output of the fission chamber in order to determine the bias required to include pulses from all modes of fission while keeping the accidental alpha pile-up rate to a negligible level.

All pulses in the scintillation detector of energy greater than that equivalent to a 350-kev gamma ray were accepted. The gain of the over-all system associated with the liquid scintillator was frequently checked by observing the 4.43-Mev gamma ray from C^{12} (obtained from the $\mathrm{Be}^9(\alpha,n)\mathrm{C}^{12}$ reaction).

In the 4197 fissions recorded, a total of 7029 pulses were observed. The background was determined by randomly triggered oscilloscope sweeps. The average background rate was found to be 0.123 ± 0.008 pulses per 40 microsecond sweep, and no significant deviation from a Poisson distribution in time was observed. By using 2.20 ± 0.03 for the average number of prompt neutrons per spontaneous fission[4,5] of Pu^{240} the efficiency of the scintillation detector for fission spectrum neutrons was determined. The efficiency, α, thus obtained was, together with its probable error, 0.716 ± 0.012.

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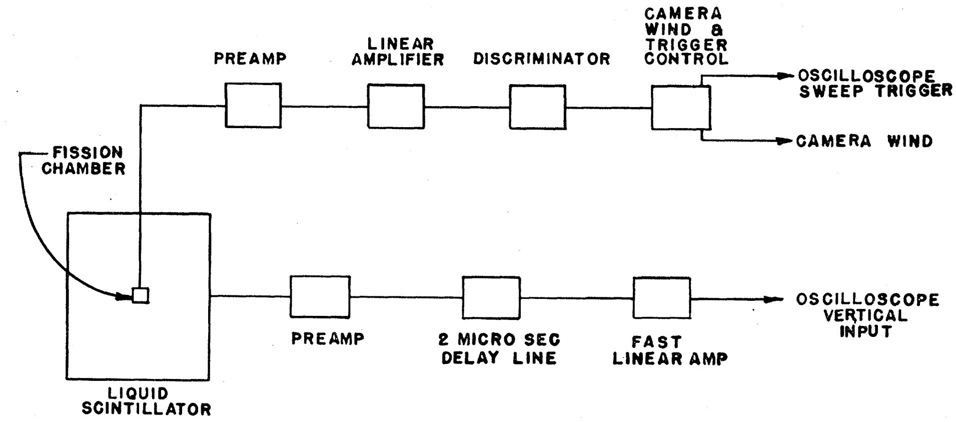

FIG. 1. Experimental arrangement.

The conversion from the distribution in the number of counter pulses per fission to the actual distribution in the number of neutrons per fission consists of corrections for resolving time, background, and counter efficiency.

The correction for the finite resolving time must be made prior to the correction for background. The probability that pulses are unresolved is derived from the observed time distribution of the capture gamma-ray pulses with the background included. $F(t)$, the time distribution of pulses per microsecond, after normalization to unity is shown in Fig. 2.

The elementary probability that two pulses are unresolved when they are within the 40 microsecond sweep is:

$$s=\tau\int_0^{40\ \mu\text{sec}}[F(t)]^2dt, \tag{1}$$

where τ is the resolving time for two pulses.

An application of this elementary probability to the observed distribution, q_n', of pulses per fission gives the relation

$$q_n=\left[q_n'-\binom{n+1}{2}q_{n+1}s\right]\bigg/\left[1-\binom{n}{2}s\right], \tag{2}$$

where q_n is now the distribution corrected for resolving time. $\binom{n}{2}$ is the binomial coefficient $n!/2!(n-2)!$.

The background correction is then made considering the probability, B_m, of m background pulses per sweep. The q_n found by means of relation (2) are related to the actual distribution of neutron pulses, Q_n, by

$$q_n=\sum_{m=0}^{n}B_mQ_{n-m}. \tag{3}$$

A solution of Eqs. (3) yields, Q_n, the actual distribution of neutron pulses per fission.

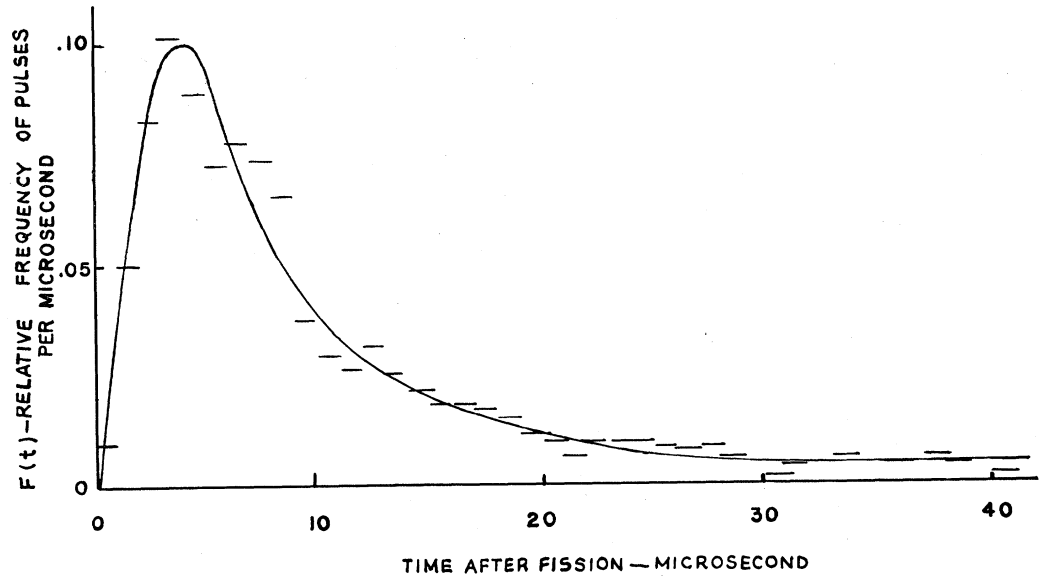

FIG. 2. Time distribution of pulses per microsecond.

TABLE I. Emission probabilities.

P_0	P_1	P_2	P_3
0.062±0.006	0.198±0.017	0.374±0.022	0.228±0.024
P_4	P_5	P_6	
0.114±0.022	0.027±0.013	0.000±0.005	

The final conversion to the probabilities, P_m, for the emission of m neutrons per fission is made considering the efficiency, α, of the counter. The actual distribution, Q_m, in the number of pulses is related to the emission probabilities, P_m, by the binomial distribution,

$$Q_n=\sum_{m=n}^{\infty}\alpha^n(1-\alpha)^{(m-n)}\binom{m}{n}P_m. \tag{4}$$

The inverse of the expression may be readily obtained, yielding

$$P_m=\sum_{n=m}^{\infty}(\alpha-1)^{(n-m)}\alpha^{-n}\binom{n}{m}Q_n. \tag{5}$$

The resultant emission probabilities obtained through the conversion outlined in the foregoing are given in Table I.

The probable errors attached to the emission probabilities in Table I were obtained by calculating the effect of independent variations in the parameters used in calculating the emission probabilities. The root sum square of the variations in the emission probabilities caused by one standard deviation in the parameters gave the standard deviation in the emission probabilities. The variations considered were those on α, s, B_m, and q_n'.

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Nuclear Scattering of Low-Energy Photons*

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The elastic photon scattering cross sections at 90° for lead, indium, cadmium, and copper have been measured between 0.5 and 3.0 Mev. Besides the expected Rayleigh scattering by bound electrons and Thomson scattering by the nucleus, a scattering component due to nuclear excitation is evident in the cross sections. The mechanism of this scattering is discussed.

NUCLEAR scattering of photons has been the subject of several recent experiments, partly because of interest in the process itself and partly because it represents a means of investigating nuclear photon capture cross sections. The latter reason is particularly important at energies below particle-emission thresholds, where elastic and inelastic photon scattering are the only possible photonuclear reactions. The experiment reported below was an attempt to observe nuclear photon capture by means of elastic scattering at very low energies (0.5 to 3.0 Mev) where the capture cross section is just beginning to rise toward the dipole resonance.

Previous work in this low-energy region has all been done with radioactive sources,[1–7] principally Co^{60} and Na^{24}. Fuller and Hayward,[8] starting at slightly higher energies and continuing over the dipole resonance, use bremsstrahlung as a radiation source, as was done in other experiments in and above the resonance region.[9,10] Stearns[11] used the 17.6-Mev gamma ray resulting from the $Li^7(p,\gamma)$ reaction. The present experiment was performed using bremsstrahlung as the primary radiation in order to obtain a high flux of photons and continuously variable energies.

The continuous spectrum of the bremsstrahlung, however, makes it impossible to determine whether a given scattered quantum resulted from an elastic or an inelastic event, since the energy involved in the capture transition is in doubt by the difference between the energy of the scattered quantum and the electron beam energy. This uncertainty was minimized here by biasing

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