volume is 8.64 Mev, so that the fission barrier is 7.6_2 Mev. If this calculation is repeated for several values of β, the maximum barrier found should be an approximate saddle-point value. Unfortunately, this procedure gives barriers that are much too high. When a plot is made of the shape of the nucleus produced by the above deformation, it shows a rather marked curvature in the equatorial region and is very close to the ellipsoid elsewhere. This can be seen in Fig. 1. The saddle-point curves of Frankel and Metropolis show a much smoother variation of nuclear surface. We believe this to be the root of our difficulty in obtaining a reasonable saddle point. An increase in the maximum value of l taken should ultimately remove this trouble. However, it probably would be better to start with $(\beta^2-\mu^2)^{\frac{1}{2}}$ or $(\beta^2-\mu^2)^{\frac{1}{3}}$ in the denominator of the expression for r so that the deformation would be accentuated in the region near the poles. The integrals for the deformation energy appear to be just as readily done for these choices of r.

The ellipsoid and tangent sphere models are complementary in that the former has marked curvature in the equatorial region whereas the latter has none. It is therefore interesting to compare the respective asymmetry barriers. In the introduction of asymmetry into the ellipsoid model again a somewhat arbitrary choice has to be made as to how the elongated drop will ultimately divide. On the assumption that the split will occur at the minimum of the constriction, the choice $c_l=0.05800$ will give roughly a two to three splitting of the above ellipsoid.

For minimum ΔE the other C_l's now become: $c_l=-0.04479$, $c_2=+0.22049$, $c_4=-0.17570$. This configuration is shown also in Fig. 1. The corresponding $\Delta E=-0.8_2$ Mev so that the barrier against this asymmetry is 0.2_0 Mev, in fair agreement with the tangent cone model. If the division of fragment masses is one to two, the asymmetry barrier becomes 0.61 and 0.75 Mev for the tangent cone and the above ellipsoid, respectively. The fact that the energy barrier disfavors asymmetric fission is in agreement with previous results.[1,2]

Since the barrier is not very great, the effects of non-uniformity of nuclear charge may be important. The model of two spheres in contact and the results of Feenberg[3] on increased nuclear binding due to non-uniform charge distribution give a crude estimate of 0.1 and 0.6 Mev in favor of asymmetric fission for two to three and one to two splittings, respectively. Thus the effect of non-uniformity appears to be of the same order of magnitude and opposite in sign to the barriers calculated above. The true influence of non-uniform charge would be obtained by including it systematically in the calculations of the Coulomb energy of a saddle-point configuration.

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Gamma-Rays from Ag^{110}

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EARLY measurements on radioactive silver revealed a long-lived activity whose half-life has been variously reported[1] as being from 90 days to 300 days. From a previous investigation here on silver activated in the pile a half-life of 282 days was reported.[2] Pool[3] has found 270 days as best fitting the observations taken over several years. This value is in accord with our continued observation.

Many electron lines were noted in our first study indicating four gamma-rays as reported. In a subsequent study Siegbahn observed[4] these four, together with six additional gamma-rays.

TABLE I. Electron energies from radioactive Ag^{110}.

Electron energy (kev)	Interpretation	Gamma-energy (kev)	Electron energy (kev)	Interpretation	Gamma-energy (kev)
90.6	$K^1(47)$	116.1	630.5	K^9	657.2
112.4	$L_{1,2}{}^1(47)$	116.1	632.4	$Ph-K^{12}$	720.0
115.3	$M^1(47)$	116.0	639.5	$Ph-L^9$	655.3
347.6	$Ph(\mathrm{Pb})K^2$	435.2	650.3	K^{10}	677.0
358.8	$Ph-K^3$	446.4	652.9	L^9	656.7
382.2	$Ph-K^4$	469.8	673.2	L^{10}	677.0
410.8	K^2	437.5	673.3	$Ph-K^{13}$	760.9
410.8	$Ph-K^5$	498.4	678.6	K^{11}	705.3
419.3	K^3	446.0	696.0	K^{12}	722.7
441.0	L^3	444.8	700.8	L^{11}	704.6
444.3	K^4	471.0	717.3	L^{12}	721.1
451.5	$Ph-K^6$	539.1	727.8	$Ph-K^{14}$	815.4
467.3	L^4	471.1	737.2	K^{13}	763.9
472.3	K^5	499.0	758.4	L^{13}	762.2
484.4	$Ph-K^7$	572.0	763.0	M^{13}	763.8
494.9	L^5	498.7	790.7	K^{14}	817.4
514.7	K^6	541.4	793.7	$Ph-K^{15}$	881.3
530.2	$Ph-K^8$	617.8	847.4	$Ph-K^{16}$	935.0
537.8	L^6	541.6	857.4	K^{15}	884.1
548.4	K^7	575.1	880.2	L^{15}	884.0
567.7	$Ph-K^9$	655.3	910.4	K^{16}	937.1
571.8	L^7	575.6	932.0	L^{16}	935.8
588.6	$Ph-K^{10}$	676.2	1293	$Ph-K^{17}$	1381
592.3	K^8	619.0	1357	K^{17}	1384
616.1	$Ph-K^{11}$	703.7	1377	K^{18}	1504

Continued investigation using photographic spectrometers and observing electrons due both to internal conversion and to photoemission from lead reveals a large number of previously unobserved electron lines. In order to have a source with greater specific activity, one irradiation was carried out in the Chalk River pile with its greater neutron flux. From measurements of the electron energies 18 gamma-rays can be identified and evaluated as associated with the radioactive decay. There is very good evidence that in the region from 400 to 600 kev additional gamma-rays exist but that their electron lines are too weak to be measured with sufficient accuracy, and hence they are not included in this report.

A summary of the electron energies together with their interpretation is presented in Table I. It is noted that the K–L–M differences for the first three electron lines are characteristic of silver and thus represent a gamma-ray emitted in a transition between isomeric states of silver. For all other conversion electron energies the K–L–M differences which fit best are those for cadmium. This indicates that competing decay processes occur, in one of which gamma-emission to a metsatable state is followed by beta-decay, whereas in the other decay mode beta-emission occurs

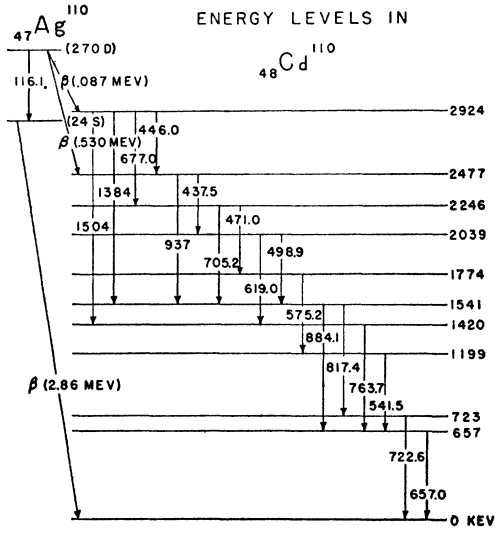

FIG. 1. Energy levels associated with the decay of radioactive Ag^{110}.

TABLE II. Summary of the gamma-rays associated with the decay of Ag^{110}. Legend: *S*—strong, *M*—medium, *W*—weak.

Arbitrary number	Energy (kev)	Intensity	Arbitrary number	Energy (kev)	Intensity
1	*116.1	*S*	10	677.0	*M*
2	437.5	*W*	11	705.2	*M*
3	446.0	*M*	12	722.6	*W*
4	471.0	*W*	13	763.7	*M*
5	498.9	*W*	14	817.4	*W*
6	541.5	*W*	15	884.1	*S*
7	575.2	*W*	16	937	*M*
8	619.0	*M*	17	1384	*W*
9	657.0	*S*	18	1504	*W*

* In silver.

first followed by multiple gamma-transitions. The many gamma-rays are assigned arbitrary numbers increasing in the order of increasing energy and are shown collectively in Table II. Every gamma-energy was derived from both photoelectric and conversion electron energies. The photoelectric energies are distinguished in Table I by the abbreviation "*Ph.*"

This many gamma-rays may be accommodated remarkably well by a level scheme as shown in Fig. 1. This arrangement utilizes the beta-energies and the gamma-rays observed by Siegbahn in somewhat the manner proposed except that certain of the energy values are modified by our measurements and the new transitions are added. The complex beta-spectrum, with upper limits at 0.087, 0.530, and 2.86 Mev, fits satisfactorily the proposed arrangement.

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The $V^{51}(p,n)Cr^{51}$ Neutron Spectrum*

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THE relatively low (p,n) threshold for vanadium[1] (1.564 Mev) and the ease of preparing thin and rugged evaporated targets of this metal suggest the use of the reaction $V^{51}(p,n)Cr^{51}$ as a monoergic neutron source at low energies.[2,3] From a study of the neutron spectrum at proton-bombarding energies well above the threshold, information can be obtained concerning the positions of excited levels of the residual nucleus, Cr^{51}, and the relative transition probabilities from the compound nucleus to these levels. These data allow conclusions concerning the monoergic nature of this source.

A 25-kev target on a tantalum backing was bombarded by 3.23- and 3.72-Mev protons from the Rockefeller electrostatic generator. Proton energies were measured by a generating voltmeter calibrated by the $Li^7(p,n)$ threshold at 1.882 Mev. The vanadium used contained 10 percent iron as impurity. This impurity was unimportant because: (a) the proton-bombarding energies were below the (p,n) threshold for the principal iron isotope (Fe^{56}: 91.6 percent),[4] and (b) the abundance of the other iron isotopes is small enough to be neglected in the present experiment.

Eastman NTB plates of 200μ thickness were placed a mean distance of 18 cm from the target in the forward direction. After the plates had been processed, proton recoil tracks within 10° of the neutron direction were measured with a microscope equipped with an oil immersion objective. The range-energy relation used to convert proton recoil track lengths to neutron energy E_n was obtained by measuring the $Li^7(p,n)$ spectrum at several bombarding energies. The resulting distributions for vanadium, corrected for the varying neutron-proton collision cross section to represent relative neutron intensities, are shown in Fig. 1.

TABLE I. Measured *Q*-values for the neutron groups shown in Fig. 1. The intensities are in each case relative to the ground-state peak *A*. The last column gives the excitation energy difference between *Q*-values for neutron groups, above the ground state, of levels in the residual nucleus Cr^{51}.

Neutron group	*Q*-values (Mev) $E_p=3.23$	$E_p=3.72$	Intensities $E_p=3.23$	$E_p=3.72$	Excitation energy (ΔQ in Mev)
A	−1.53	−1.55	1	1	
B	−2.30	−2.33	0.33±0.05	0.44±0.07	0.775±0.050
C	−2.69	−2.72	0.31±0.05	0.55±0.08	1.165±0.050
D		−2.97		0.30±0.05	1.420±0.080
E		−3.08		0.30±0.05	1.530±0.080

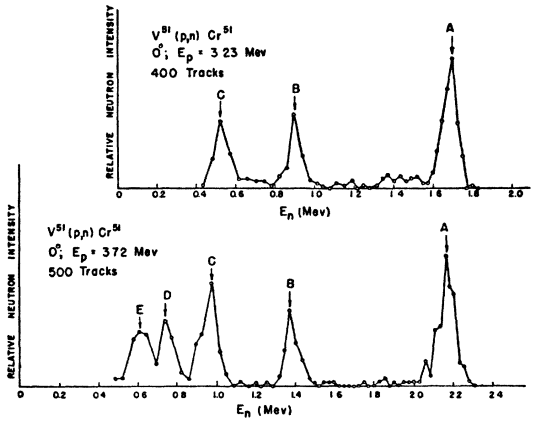

FIG. 1. Relative neutron intensity *vs.* neutron energy E_n for $V^{51}(p,n)Cr^{51}$ reaction using protons of energy E_p. Intensities include correction for variation of n–p scattering cross section with energy. Neutrons of known energy from the $Li^7(n,p)Be^7$ reaction were used to determine directly the range-energy relation for the photographic plates.

The peaks designated by *A* give *Q*-values which are in excellent agreement with that obtained from the threshold measurement of Smith and Richards.[1] Hence, the peaks at *A* correspond to neutrons which leave Cr^{51} in the ground state. Two additional peaks, designated by *B* and *C*, are of lower energy, have intensities comparable to *A*, and presumably indicate the existence of excited states in Cr^{51}. Two less well-defined groups, *D* and *E*, appeared with higher energy protons. The measured *Q*-values of these groups and the intensities relative to the ground state are given in Table I.

In Fig. 1, the curve for $E_p=3.23$ Mev gives almost 10 percent as the upper limit for the intensity, relative to the ground-state peak, of any possible neutron peak between *A* and *B*. Poor generator performance during this run may have increased the neutron background. The more satisfactory run at $E_p=3.72$ Mev gives approximately three percent as an upper limit for a peak between *A* and *B*. Therefore, the $V^{51}(p,n)$ reaction should furnish monoergic neutrons (within these limits) up to $E_n=775\pm50$ kev.

* Assisted by the joint program of the ONR, AEC, and BuShips.
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