experiments [Fig. 1(b)]. The evaluation of the maximum (or minimum) angle between the $\alpha$-particles from the $Be^8$ nucleus, for any given excited state and at any incident neutron energy, enabled the excited state of the $Be^8$ nucleus involved in 269 of the stars to be fixed uniquely. A histogram of these values is shown in Fig. 1(c).

The positions and widths of the excited states found agree, in general, with those observed by Green and Gibson,[3] using the reaction $Li^7(d, n)Be^8$, and by Richards.[4] No ground state was indicated although it is possible that stars of this type escaped observation owing to the very small angle between the $\alpha$-particles emitted from this state.

The excited level at 5 Mev previously observed was not taken into account, as there seems to be good evidence for believing that a $\gamma$-ray is emitted from this level and that disintegration into two $\alpha$-particles is forbidden. Some of the stars in group (d) can be accounted for in this way. However, the calculations performed on stars due to the $B^{10}(n, H^3)2\alpha$ reaction, where the direction of the incident neutron can be calculated instead of being assumed, show that most of the stars in group (d) originated from scattered neutrons.

No deviation from isotropy within the rather large limits of statistical error was found for the angular distribution of $\alpha$-particles from the intermediate $Be^8$ nucleus in the center-of-mass coordinates of that nucleus for either reaction. A deviation from isotropy was indicated, however, in the angular distribution of the triton emitted in the first state of the reaction $B^{10}(n, H^3)2\alpha$.

From these results the percentage probability of a particular excited state ($y$) of $Be^8$ being formed in a nuclear event can be deduced. Figure 2 shows graphs of this percentage probability against incident neutron energy for the excited state found in the two reactions. The curves were drawn using the relation

$$\text{percentage probability} = (P_y/\Sigma_y P_y)\times 100,$$

where $P_y$ is the total probability of an excited state, $y$ being formed independently of the competition of other excited states. It was found that the experimental points could be best fitted if it were assumed that

$$P_y \propto x_y \exp(-Kx_y),$$

where $x_y$ is the excess incident neutron energy above the threshold for the formation of an excited state $y$, and $K$ is a constant.

Using only one value of $K$ for each reaction, a fit was obtained for the variation of the percentage probability of the formation of all the excited states. Now the total probability, $P_y$, can be considered as a product of two factors, one being the internal probability of formation and the other being the penetrability factor. The latter is initially the dominant factor leading to a sharp rise from the threshold energy to the top of the potential barrier.

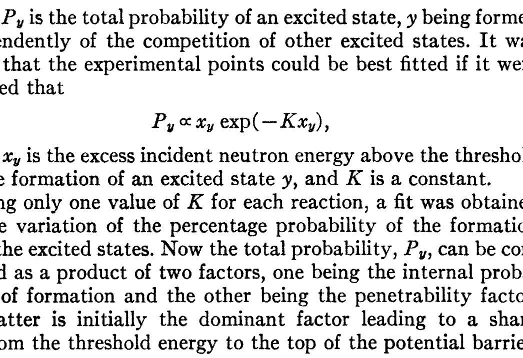


FIG. 2. The percentage probability (percent $P_y$) for the formation of the excited states of the intermediate nucleus $Be^8$ in the reactions $C^{12}(n, n)3\alpha$ and $B^{10}(n, H^3)2\alpha$. The excited states of $Be^8$ are given by (a) =2.65, (b) =4.0, (c) =7.25, (d) =9.8, (e) =13.5 Mev. The curves were calculated using the relation $P_y=x_y\exp(-Kx_y)$, where $K=0.1$ for the $C^{12}(n, n)3\alpha$ reaction and $K=0.3$ for the $B^{10}(n, H^3)2\alpha$ reaction.

Support for this view is forthcoming from the positions of the maxima in the two curves for $P_y$ corresponding to the values for $K$ obtained for the two reactions. It is found that they correspond to the excess incident neutron energy required to allow the triton and $\alpha$-particle to escape over the top of the potential barriers of the compound nuclei $C^{13}$ and $B^{11}$, respectively.

My thanks are due Dr. Burcham for permission to use the Cavendish Laboratory cyclotron, and to the Department of Scientific and Industrial Research for financial assistance.

[1] L. L. Green and W. M. Gibson, Proc. Phys. Soc. (London) **62**, 296 (1949).
[2] L. L. Green and W. M. Gibson, Proc. Phys. Soc. (London) **62**, 407 (1949).
[3] W. F. Hornyak and T. Lauritsen, Revs. Modern Phys. **20**, 191 (1948).
[4] H. T. Richards, Phys. Rev. **59**, 796 (1941).

## Fission in $Am^{242}$

G. C. HANNA, B. G. HARVEY, N. MOSS, AND P. R. TUNNICLIFFE*
*Atomic Energy Project, National Research Council of Canada, Chalk River, Ontario, Canada*
January 8, 1951

SLOW neutron irradiation of $Am^{241}$ produces a nuclide with a large slow neutron fission cross section. Chemical separation in ion-exchange resin columns shows that the fission is due to an americium isotope. The growth of fission rate with pile irradiation shows that $Am^{242}$ g sec (the long-lived ground state) is responsible. Values for its fission and capture cross sections have been obtained.

Americium samples for fission measurements were prepared by ion-exchange separation of the americium from the irradiated $Am^{241}$. Sources were prepared (in most cases) by evaporation of the purified americium onto smooth platinum disks from a tantalum or wolfram filament at 2000°C. The $Am^{241}$ in each source was estimated by $\alpha$-counting in a low geometry proportional counter.[1] The fission rate in a neutron beam $\frac{1}{2}$ in. in diameter was measured using the fission chamber recently described.[2] The neutron beam intensity (about $4.5\times10^8$ neutrons/cm²/sec) was monitored with a $Pu^{239}$ source mounted in a separate shallow chamber in the same beam. In earlier experiments[3] we have measured the total cross section, $\sigma_1$, of $Am^{241}$, and the partial cross section, $f\sigma_1$, for $Cm^{242}$ production. (In fact, the samples used in that investigation also appear here as Nos. 3 to 7 inclusive.) Values of the $Am^{241}$ destruction parameter, $\sigma_1\int(\rho v)dt=at$, were calculated with the aid of the pile operating log.

If $g\sigma_1$ is the partial cross section for the formation from $Am^{241}$ of $Am^{242}$ g sec and if the latter has a total cross section of $\sigma_2=n\sigma_1$, then it can be shown that after irradiation ($Am^{242}$ g sec)/($Am^{241}$) $=[g/(n-1)]\{1-\exp[-(n-1)at]\}$. The specific fission rate (fission counts per $10^6$ $\alpha-dpm$ of $Am^{241}$ in a neutron beam of standard intensity) will then be of the form $N=N_1+N_2\times\{1-\exp[-(n-1)at]\}$. $N_1$ is the fission rate of $Am^{241}$, and $N_2$ is the "saturation" fission rate of $Am^{242}$ g sec.

The fission cross section of $Am^{241}$ was determined separately as 3.0 barns, giving $N_1=28.8$ cpm in the standard neutron beam. Other subsidiary experiments gave fission cross sections of about 20 barns and 5 barns (as an upper limit) for $Pu^{238}$ and $Cm^{242}$. These latter figures were required (along with the spontaneous fission rate of $Cm^{242}$)[2] for making very small corrections to the rather lightly irradiated sources (Nos. 4, 5, and 6), since these were not subjected to chemical separation.

Figure 1 shows the experimental values of $(N-N_1)$ and the theoretical curves for $n=8$, 9, and 10. The value $n=9$ gives the best fit, but the "scatter" in the results is greater than our estimated error. This may arise partly from variations in the neutron energy spectrum between different pile irradiation-positions, particularly if a strong resonance were involved, since several widely separated irradiation-positions were used and at widely differing times.

Taking[3] $n=9$ and $\sigma_1=887$ barns, we obtain for $\sigma_2$, the total $Am^{242}$ g sec cross section, 8000 barns. This does not involve a

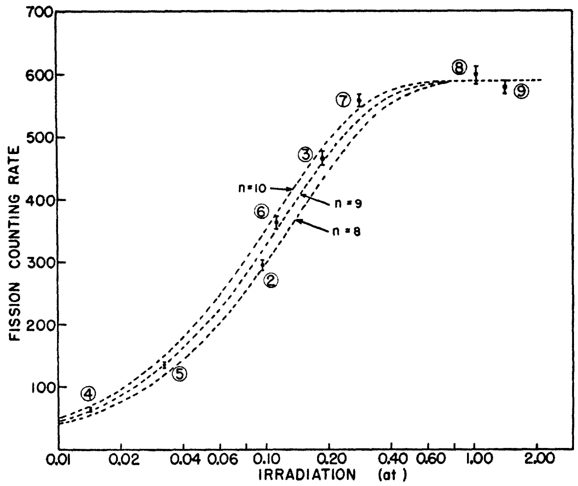


FIG. 1. The relation between $Am^{242}$ fission rate (corrected for the presence of $Am^{241}$) and irradiation. The fission rate is expressed in counts/min per $10^6$ $\alpha$-*dpm* of the accompanying $Am^{241}$ in a flux of $4.5\times10^8$ neutrons/cm²/sec. The abscissas are in units of $at=\sigma_1\int(\rho v)dt$, which measures the destruction of $Am^{241}$.

knowledge of $g$, that is, of the actual amount of $Am^{242}$ g sec present. However, the deduction of the fission cross section ($\sigma_{2f}$) does involve $g$. On comparison of the saturation fission rate of $Am^{242}$ g sec with that of the $Pu^{239}$ monitor, we obtain $\sigma_{2f}=500/g$. Recently O'Kelley and co-workers[4] gave a value of 0.2 for the I.T. branching ratio of $Am^{242m}$; this is clearly a lower limit for $g$, but probably a fairly close one.[3] With $g=0.2$, $\sigma_{2f}=2500$ barns; and hence the capture cross section is 5500 barns.

The shape of the curve (Fig. 1) in the very heavy irradiation region shows that any contribution from fission in $Am^{243}$ is negligible. Taking $g=0.2$, we obtain an upper limit of about 25 barns for the fission cross section of $Am^{243}$.

It is a pleasure to acknowledge our debt to Mr. Philip B. Aitken for the design of equipment used in the handling of large $\alpha$-activities.

* Now at Atomic Energy Research Establishment, Harwell, England.
[1] Hanna, Harvey, and Moss, Phys. Rev. **78**, 617 (1950).
[2] Hanna, Harvey, Moss, and Tunnicliffe, to be published.
[3] Hanna, Harvey, and Moss, to be published.
[4] O'Kelley, Barton, Crane, and Perlman, Phys. Rev. **80**, 293 (1950).

## Note on Soft Gamma-Component of Cosmic Rays*

F. G. REST, L. REIFFEL, AND C. A. STONE
*Armour Research Foundation of Illinois Institute of Technology, Chicago, Illinois*
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THE soft gamma-component of cosmic rays has been studied at 30,000 feet using the G-M counter geometry illustrated in Fig. 1. This arrangement minimizes the effects of dead space between tubes and the intrinsic inefficiency of the tubes for ionizing particles. Copper tubes with 0.031-inch walls were used to absorb Compton electrons with energies greater than 2 Mev. $A-B$ ($A$ without $B$) counts, therefore, correspond to gamma-rays of energy less than 4 Mev. This nominal high energy cutoff is not sharp, owing to the distribution of Compton electrons and the geometry of the detector.

TABLE I. Counting rates at 30,000 feet.

| Radiation | Counting rate | Omnidirectional flux |
|---|---|---|
| $A-B$ (soft gamma) | $78\pm2$ cpm | 3.4 photons cm$^{-2}$ sec$^{-1}$ |
| $AB$ (ionizing) | $718\pm6$ cpm | 0.45 particles cm$^{-2}$ sec$^{-1}$ |
| $A$ (both) | $797\pm6$ cpm | 3.9 rays cm$^{-2}$ sec$^{-1}$ |

$A-B$, $AB$, and $A$ counts were observed simultaneously with circuits of 1 $\mu$sec resolution. The data thus obtained, corrected for aircraft contamination, are given in Table I.

The omnidirectional $A-B$ flux was calculated assuming a mean counter efficiency of 1 percent for photons.[1] There is good agreement between this observed photon flux and that calculated from the area under the gamma-ray portion of the cosmic-ray pulse distribution curve obtained with a scintillation counter and a differential analyzer.[2] (For a 10-percent mean crystal efficiency the scintillation data yields 3.8 photons cm$^{-2}$ sec$^{-1}$.)

The calculation of the omnidirectional $AB$ flux is based on a measured mean counter efficiency of 97 percent and a cosine squared variation with zenith angle.[3] The value obtained here compares closely with an interpolated value of 0.48 particle cm$^{-2}$ sec$^{-1}$ at 30,000 feet, using the estimates given by Montgomery.[4]

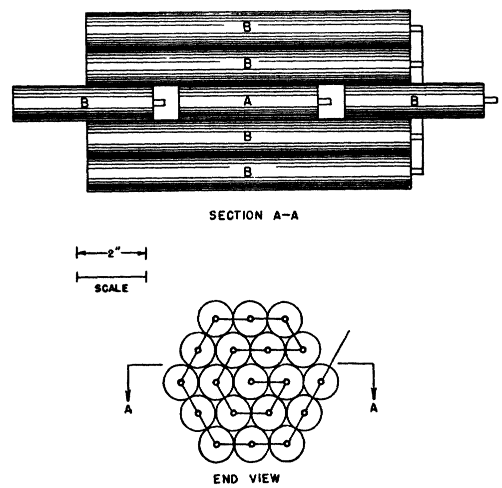


FIG. 1. Detector for soft gamma-radiation.

These investigations are being carried further, and data regarding altitude and directional intensity variations will be presented in a future publication.

* This work has been performed as one aspect of a project carried on under contract with the United States Department of the Air Force.
[1] H. Bradt, *et al.*, Helv. Phys. Acta **19**, 77 (1946).
[2] Reiffel, Stone, and Rest, to be published.
[3] Biehl, Neher, and Roesch, Phys. Rev. **76**, 914 (1949).
[4] D. J. X. Montgomery, *Cosmic Ray Ray Physics* (Princeton University Press, Princeton, 1949), p. 131.

## Detection of Positive $\pi$-Mesons by $\pi^+$ Decay*

M. JAKOBSON,** A. SCHULZ, AND J. STEINBERGER†
*Radiation Laboratory, University of California, Berkeley, California*
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POSITIVE $\pi$-mesons have been detected by means of a delayed coincidence between a $\pi^+$ meson and its decay $\mu^+$ meson. This method is similar to that of previous investigators[1-3] who have used the characteristic $\mu^+-\beta^+$ decay for meson detection.

A polyethylene target bombarded by the photon beam of the Berkeley synchrotron provided a source of mesons. Two trans-stilbene crystals in the form of a counter telescope were placed 90° from the direction of the photon beam. The scintillations from the crystals were detected and amplified by 1P21 photo-multipliers. The photo-multiplier pulses, caused by a $\pi^+$ meson passing through one crystal and stopping in the second, open a gate of width 0.08 $\mu$sec which is then delayed 0.025 $\mu$sec. If the $\mu^+$ meson pulse arising from the decay of the stopped $\pi^+$ meson appears during the time the gate is open, the meson is counted