voltage measurement being made by a standard cell potentiometer which also served to monitor the photo-tube supply voltage.

The source of K^{40} was 25 lb of normal potassium carbonate in a box surrounding the crystal housing (Fig. 1). The beta-shield was 1.5-mm brass in this experiment. For comparison spectra, Co^{60} and Zn^{65} were used. They were placed at position *I* (Fig. 1) to minimize scattering effects.

Photo-tube gain was monitored during the data run by means of a standard source of gamma-radiation placed at position *II*. Gain shifts of one or two percent were encountered and corrected.

The differential pulse height distributions of Zn^{65}, Co^{60}, and K^{40} were recorded, corrections being made for amplifier linearity and window width variations. The K^{40} background was subtracted from the comparison spectra. For the K^{40} itself, background was negligible. The data (Fig. 2) show photo-electron lines well resolved from the Compton distributions. The annihilation quanta of the (≈ 3 percent abundant) positrons[1] of Zn^{65} yield a prominent photo-electron line (P_2). The Compton edge is lost in the counts arising from backscattered radiation. The photo-electron line

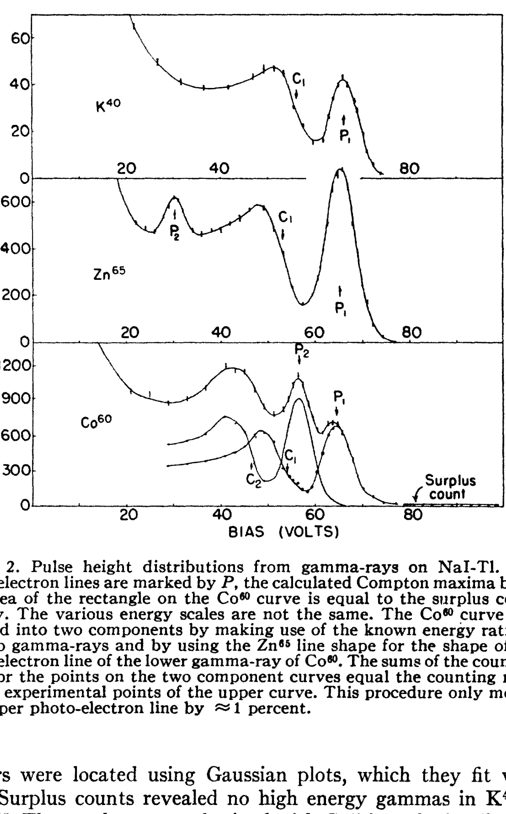

FIG. 2. Pulse height distributions from gamma-rays on NaI-Tl. The photo-electron lines are marked by *P*, the calculated Compton maxima by *C*. The area of the rectangle on the Co^{60} curve is equal to the surplus count at 79 v. The various energy scales are not the same. The Co^{60} curve was resolved into two components by making use of the known energy ratio of the two gamma-rays and by using the Zn^{65} line shape for the shape of the photo-electron line of the lower gamma-ray of Co^{60}. The sums of the counting rates for the points on the two component curves equal the counting rates for the experimental points of the upper curve. This procedure only moved the upper photo-electron line by ≈ 1 percent.

centers were located using Gaussian plots, which they fit very well. Surplus counts revealed no high energy gammas in K^{40} or in Zn^{65}. The surplus count obtained with Co^{60} is undoubtedly due to coincident counting of the two cascade gammas. Using the Co^{60} upper gamma-ray as standard[2] at 1.332 ± 0.001 Mev, the energies determined from these curves are:

K^{40}: 1.459 ± 0.007 Mev

Zn^{65}: 1.127 ± 0.009 Mev (accepted value[3] 1.118 Mev).

This work was performed independently and confirms the results of the nearly identical experiment of Bell.[4] Bell obtained 1.462 ± 0.01 Mev for the K^{40} gamma-ray energy.

The measured energy of the annihilation quantum line (0.520 Mev) is a little larger than the accepted value (0.511 Mev), probably because of the shape of the large background on which the line stands. This is analogous to the effect reported by Bell[5] in which m_0c^2, as determined by subtracting pair-peak from photo-peak energies, is consistently too low.

The error given for K^{40} is smaller than that for Zn^{65} because in the case of K^{40}, the comparisons to the standard source were made without turning the tube off, and hence are more consistent. About two-thirds of the errors arise from tube gain shifts.

The author wishes to express his indebtedness to Drs. Walter M. Nielsen and Henry W. Newson for their cooperation in this work.

† This work was supported in part by joint contract with ONR and AEC.

[1] W. M. Good and W. C. Peacock, Phys. Rev. **69**, 680 (1946).
[2] Lind, Brown, and DuMond, Phys. Rev. **76**, 591A, 1838 (1949).
[3] Jensen, Laslett, and Pratt, Phys. Rev. **76**, 430L (1949).
[4] Bell and Cassidy, Phys. Rev. **79**, 173L (1950).
[5] Bell, Science **112**, 7 (1950).

The Fast Neutron Disintegration of C^{12} and B^{10}

J. L. PERKIN
Wheatstone Physics Laboratory, King's College, London, England
January 8, 1951

BORON-LOADED nuclear research emulsions were exposed to neutrons with energies extending up to 24 Mev. The neutrons were produced from a lithium target bombarded by 7-Mev deuterons from the Cavendish Laboratory cyclotron.

Calculations similar to those described by Green and Gibson[1] were carried out to identify the 700 disintegration stars observed in the emulsion with the following results: (a) 485 stars caused by the $C^{12}(n, n)3\alpha$ reaction, (b) 100 stars caused by the $B^{10}(n, H^3)2\alpha$ reaction, (c) 35 stars which could have been caused by either reaction, (d) 80 stars which did not satisfy either of the calculations.

The disintegration of the compound nuclei C^{13} and B^{11} formed in these reactions may proceed through a number of possible intermediate stages. If the experimental values for the energies of the emitted particles are used, the excited states of the nuclei involved in these various possible modes of disintegration can be calculated for each star. Comparison of the results with the values of the excited states found in previous experiments[2] shows that most, if not all, of the disintegrations proceeded via an intermediate stage involving the Be^8 nucleus.

A histogram of the values of the excited states of Be^8 for the $B^{10}(n, H^3)2\alpha$ reaction is shown in Fig. 1(a). Although statistically weak, the histogram does indicate levels at points previously reported.

The results for the reaction $C^{12}(n, n)3\alpha$ are complicated by the fact that the identities of the two α-particles associated with the disintegration of the intermediate nucleus Be^8 are not known. If all possible values for the energy of the excited state of Be^8 are plotted (i.e., three per star), the significant values appear as peaks on a continuous background at points known from other

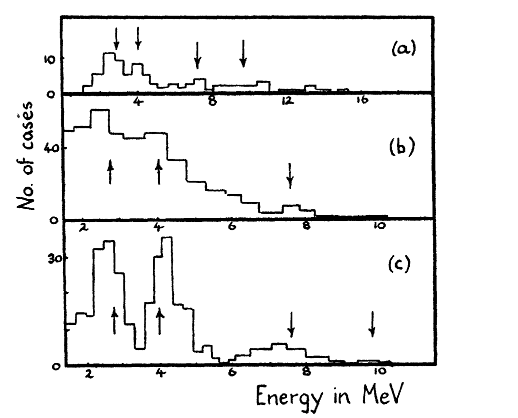

FIG. 1. Excited states of the intermediate nucleus Be^8: (a) from the reaction $B^{10}(n, H^3)2\alpha$, (b) from the reaction $C^{12}(n, n)3\alpha$ (all possible values), (c) from the reaction $C^{12}(n, n)3\alpha$ (unique values). The arrows refer to the values of the excited states previously known.

experiments [Fig. 1(b)]. The evaluation of the maximum (or minimum) angle between the α-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 α-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 γ-ray is emitted from this level and that disintegration into two α-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 α-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.

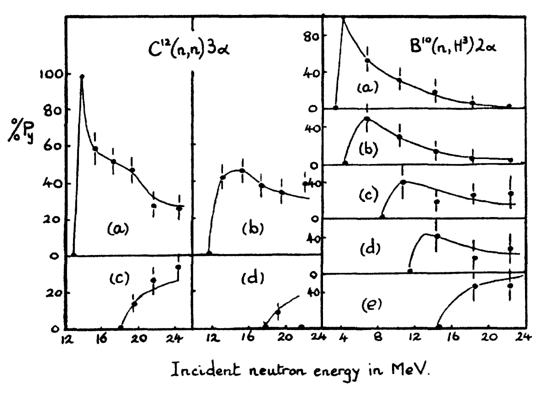

FIG. 2. The percentage probability (percent P_y) for the formation of the excited states of the intermediate nucleus Be^8 in the reactions $C^{12}(n, n)3\alpha$ and $B^{10}(n, H^3)2\alpha$. The excited states of Be^8 are given by (a) =2.65, (b) =4.0, (c) =7.25, (d) =9.8, (e) =13.5 Mev. The curves were 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 α-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 α-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 4.5×10^8 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, σ_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 σ_1 = 887 barns, we obtain for σ_2, the total Am^{242} g sec cross section, 8000 barns. This does not involve a