is to observe the $\mu - e$ decay at the end of the μ track. Further investigation of the decay should indicate whether the branching ratio of the two modes of decay is governed by the half-lives or perhaps also by other considerations.

The author wishes to thank Dr. D. C. Peaslee for several helpful discussions.

* Work performed under the research program of the U. S. Atomic Energy Commission.

† Since this work was completed a similar article by L. Michel and R. Stora, Compt. rend. **234**, 1257 (1952) has been noted. However, by using a specific form of the interaction, both the half-life and the spectral shapes can be determined more definitely. Further, smaller and more recent estimates of the rest mass are used.

[1] C. O'Ceallaigh, Phil. Mag. **42**, 1032 (1951); R. B. Leighton and S. D. Wanlass, Phys. Rev. **86**, 426 (1952). Most of the experimental data on κ mesons used was presented at a recent seminar here by L. Leprince-Ringuet.
[2] L. Michel, Proc. Phys. Soc. (London) **A63**, 514 (1950).
[3] D. C. Peaslee, Phys. Rev. (to be published).
[4] W. L. Alford and R. B. Leighton, Phys. Rev. **90**, 622 (1953).

Scintillation Study of As^{77} and Br^{77}†

M. E. Bunker, R. J. Prestwood, and J. W. Starner
Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico
(Received June 24, 1953)

PREVIOUS investigations[1–3] have suggested that no gamma radiation is emitted in the decay of As^{77} (39 hr). However, a careful study of this isotope by scintillation techniques has revealed the presence of eight gamma rays with energies and intensities as given in Table I.

Identical spectra were observed from samples of As^{77} produced in fission and by chemical extraction from neutron-irradiated germanium. All portions of the gamma-ray spectrum decayed with the half-life of As^{77}, which we have measured to be 38.68 $\pm$0.09 hr. γ_5 and γ_7 were found using a gamma-gamma coincidence arrangement employing a pair of scintillation spectrometers. There is evidence for other weaker gamma-rays which as yet have not been resolved. Figure 1 shows the low-energy portion of the As^{77} spectrum taken with a NaI(Tl) crystal $\frac{1}{4}$ in. thick mounted on a Dumont K-1186 photomultiplier tube. The peak at a discriminator potential of volts (~26-kev) is much too broad to be due to a single gamma ray, and the gamma-gamma coincidence measurements suggest that this peak is composed of two components having respective energies of about 23 and 28 kev. Since the energies of γ_3 and γ_4 add to 246 kev, it seems likely that these gamma rays are in series and that they parallel γ_6. The results of previous experiments[4,5] suggest that γ_4 is about 50 percent converted. Since our measurements suggest that γ_3 is only slightly converted, it can be seen from Table I that the *transition intensities* of γ_3 and γ_4 are nearly the same, lending support to the view that these gamma rays are in series. However, since both γ_4 and γ_6 had been observed in the decay of Br^{77},[3] but not γ_3, it was felt desirable to re-examine the gamma spectrum of Br^{77}.

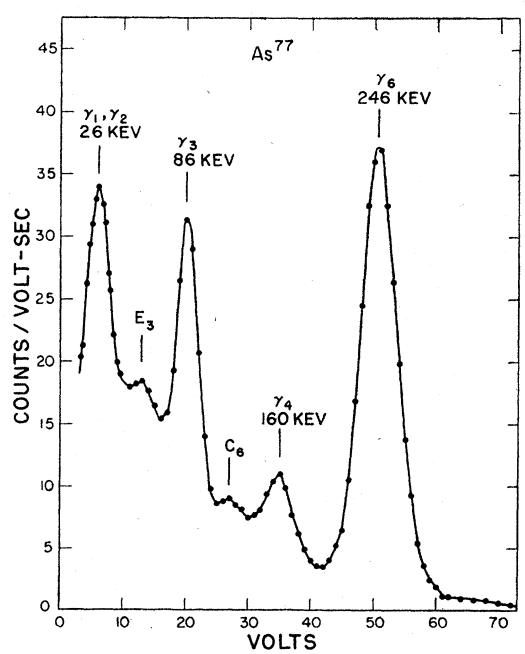

FIG. 1. Low-energy portion of the gamma-ray spectrum of As^{77} taken with a NaI(Tl) scintillation spectrometer. C_6 is the Compton peak of γ_6. E_3 is the escape peak of γ_3.

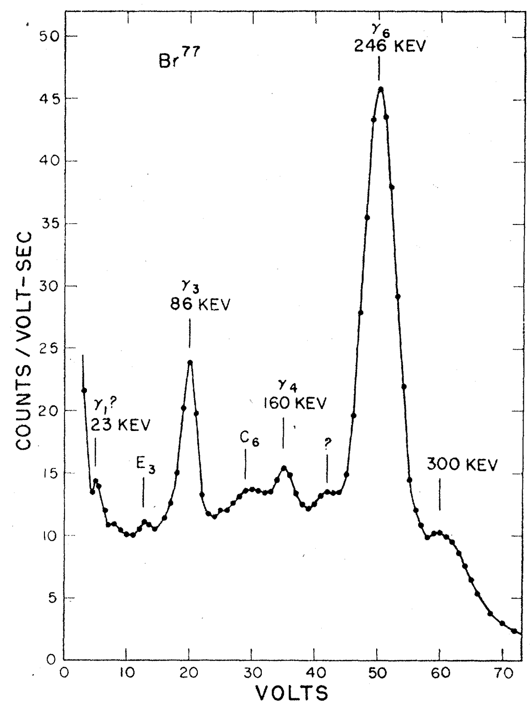

FIG. 2. Low-energy portion of the gamma-ray spectrum of Br^{77} taken with the same spectrometer as that used to obtain the As^{77} spectrum shown in Fig. 1. The sharp rise below 4 volts is due to the selenium K x-ray.

TABLE I. Gamma rays of As^{77}.

Gamma ray	Gamma energy (kev)	Normalized intensity[a] (%)
γ_1	23±2	0.14[b]
γ_2	28±2	
γ_3	86±2	0.2
γ_4	160±2	0.1
γ_5	186±4	<0.01
γ_6	246±2	1.5
γ_7	283±4	<0.01
γ_8	524±2	0.5

[a] Number of quanta relative to the total number of disintegrations.
[b] Sum of the intensities of γ_1 and γ_2.

Figure 2 shows the low-energy portion of the scintillation spectrum of Br^{77}, measured with the same equipment and in an identical geometry as that used to obtain the As^{77} spectrum of Fig. 1. γ_3 is seen to be present in about the same intensity relative to γ_4 as in the As^{77} spectrum. However, γ_3 and γ_4 seem to be weaker relative to γ_6. This is difficult to understand unless one assumes

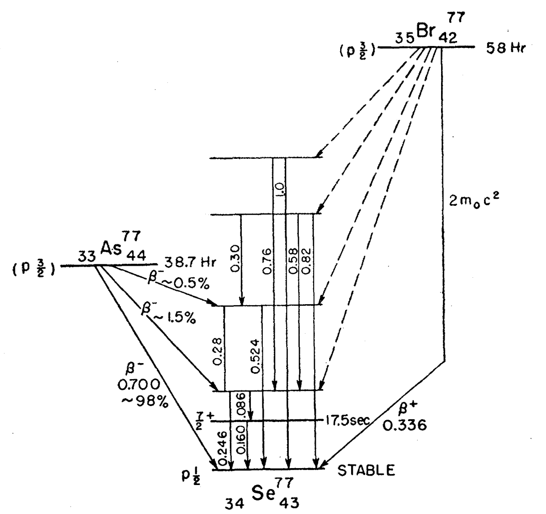

FIG. 3. Tentative partial decay scheme for As^{77} and Br^{77}.

that the γ_6 peak of the Br^{77} spectrum is actually composed of more than one component. The only other evidence that this may be true is the rather large energy discrepancy between the value reported here for γ_6 and the values reported previously[3,6] on the basis of conversion electron energies.

Another troublesome feature of the Br^{77} spectrum is the lack of a strong peak at about 6 volts. It seems likely that the ground-states of both As^{77} and Br^{77} are $p_{\frac{3}{2}}$ states; hence, one would expect any level of Se^{77} excited in the decay of As^{77} to also be excited in the decay of Br^{77}. Although there is evidence in Fig. 2 for a peak at about 23 kev, it is quite weak.

Additional gamma rays of energy 0.30, 0.524, 0.58, 0.76, 0.82, and 1.0 Mev were observed in the decay of Br^{77}. There is no evidence of the 0.641-Mev gamma ray reported previously.

A tentative partial decay scheme is shown in Fig. 3. Most of the gamma cascades have been verified by gamma-gamma coincidence measurements.

A more complete account of these experiments will be published later.

During the course of this investigation, it was learned that investigators at both Oak Ridge National Laboratory and the Bartol Research Foundation have also made measurements on the gamma rays from As^{77}.

† Work done under the auspices of the U. S. Atomic Energy Commission.

[1] Mandeville, Woo, Scherb, Keighton, and Shapiro, Phys. Rev. **75**, 1528 (1949).
[2] Jensen, Nichols, and Clement, Phys. Rev. **81**, 143 (1951).
[3] R. Canada and A. C. G. Mitchell, Phys. Rev. **81**, 485 (1951).
[4] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).
[5] Rutledge, Cork, and Burson, Phys. Rev. **86**, 775 (1952).
[6] S. C. Fultz and M. L. Pool, Phys. Rev. **86**, 347 (1952).

The Reactions $He^3(He^3, p)Li^5$ and $T(He^3, p)He^5$

E. ALMQVIST,* K. W. ALLEN,† J. T. DEWAN,‡ AND T. P. PEPPER§
Atomic Energy of Canada Limited, Chalk River, Ontario, Canada
(Received July 2, 1953)

THE ground states of Li^5 and He^5 are unstable against heavy particle emission with a lifetime of the order of 10^{-21} second. Their properties can therefore only be inferred from a study either of the scattering of protons and neutrons by helium, or of two-body nuclear reactions in which the emitted particle escapes beyond the range of nuclear forces before the dissociation of the residual Li^5 or He^5 nucleus. Two reactions of this type, $He^3(He^3, p)Li^5$ and $T(He^3, p)He^5$, have been observed in the course of a photographic plate study of He^3 induced reactions.

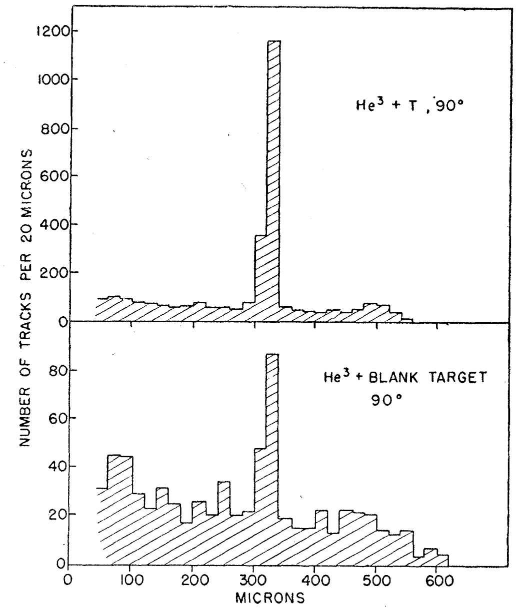

FIG. 1. Range distributions in Ilford C2 emulsions of charged particles resulting from He^3 reactions.

A beam of 0.24-Mev He^3 ions was allowed to bombard in turn a target of tritium occluded in titanium and a polished copper block. Ions from the beam were deposited in the copper block, which then acted as a He^3 target.[1] The tracks of long-range charged particles emitted at 90 degrees and 135 degrees to the beam were recorded in 200 micron Ilford C_2 emulsions. The plates exposed to the tritium target had about 10 tracks per sq mm while those exposed to the blank target with ten times the irradiation had only about 1 track per sq mm excluding the tracks of long-range protons from the $He^3(d, p)He^4$ reaction which are always present. Thus the background of disintegration particles from the He^3+He^3 reactions was negligible in the He^3+T plates. The range distribution of particles emitted at 90° to the beam are shown in Fig. 1. Energy measurements with a calibrated KI(Tl) crystal and photomultiplier combined with the range measurements allow the peak at 330 microns range to be identified as deuterons from the $T(He^3, d)He^4$ reaction.[2] The presence of this peak in the plate exposed to the *blank* target is not surprising as the H.T. set and recovery system had been used for some time to accelerate tritium so that some contamination tritons were inevitably present in the beam. However, by normalizing the distributions to the same intensity of the deuteron peak, the contribution of the He^3+T reactions was subtracted from the distribution obtained with the blank target. The resulting distribution of protons emitted at 90° from the He^3+He^3 reactions, together with that from the He^3+T reactions, is shown in Fig. 2 transformed to an energy scale.

Each of the curves in Fig. 2 consists of a group of particles superimposed on the high-energy end of a continuum. These groups are attributed to protons from the reactions $He^3(He^3, p)Li^5$ and $T(He^3, p)He^5$. The Q values for these reactions, calculated from the measured proton energies, are 10.86 ± 0.15 Mev and 11.18 ± 0.07 Mev, respectively.

Using the mass scale of Li *et al.*,[3] these Q values lead to masses of 5.01414 ± 0.00016 and 5.01382 ± 0.00007 for Li^5 and He^5. The former exceeds the combined mass of He^4+n by 0.90 ± 0.07 Mev. The width of the ground state of Li^5 is greater than that of He^5 and probably exceeds 1 Mev. These results are in agreement with other data given in a recent review article.[4]

Classical phase-space considerations lead to elliptical energy distributions for the protons from the three-body break-up.[5]