These bombardments, made with 0.25-microampere beams (meter current) did, however, at the same time produce large amounts of californium and fermium activities and were otherwise quite similar to those experiments with the moving belt in which we identified the 3-second nuclide 102^{254}.[3]

The data arguing against the validity of the Stockholm experiments on which the claim to the discovery of element 102 was based may be summarized as follows:

1. We have used curium targets with substantially the same isotopic composition and have bombarded them with C^{13}, C^{12}, and O^{16} ions over a wide energy range with monoenergetic beam currents as much as ten times greater than those of wider energy spread in the cyclotron experiments. We have used three different methods of handling the transmutation recoils from the targets; all of them were successful in that we detected large amounts of other actinide element products but nevertheless failed to produce the 10-minute, 8.5-Mev activity. That our experiments should have detected this unknown activity is made certain by the fact that one of these methods (electrostatic collection of target recoils) was used in the identification of a very short-lived isotope of element 102.

2. Our inability to confirm the Stockholm results we feel may possibly be explained by the following circumstances. The cyclotron experiment, because it had to make use of the internal beam, was an extremely difficult one to perform. The amount of activity produced varied erratically but was always very tiny; not more than a few events in any one experiment were ever seen, and in most of them none was detected. Under these trying conditions it was apparently not possible to make sure that the unknown activity could not be ascribed to a light element impurity or other artifact. In connection with this it should be noted that the one crude ion-exchange elution experiment performed showed the unknown activity to elute immediately after the free column volume, and thus did not provide a clear chemical differentiation from several possible lighter elements. It should also be noted that at the 90-Mev C^{13} energy used most of the time in the cyclotron experiments one would produce predominantly those neutron evaporation reactions where six or more neutrons would be emitted. This would limit the mass number of any isotope of element 102 that could be produced to 253 or less. It is quite conceivable that some isotope of 102 such as 102^{257} or 102^{259} could have a half-life of ten minutes, but these could only be produced by bombardment of heavier curium isotopes, even when using lower energy bombarding ions. It would also be expected that a 10-minute half-life for an isotope of element 102 would imply an alpha-particle energy for the most abundant group closer to 8.0 than to 8.5 Mev.

The only conclusion that we can draw from these observations is that the activity found by these experimenters cannot be ascribed to element 102.

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†This work was performed under the auspices of the U. S. Atomic Energy Commission.

*On leave from Joint Establishment for Nuclear Energy Research, Kjeller, Norway.

[1]A. R. Fields et al., Phys. Rev. 107, 1460 (1957).

[2]K. A. Kraus and F. Nelson, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Geneva, August, 1955, (United Nations, New York, 1956), Vol. VII, p. 113, P/837.

[3]See Ghiorso, Sikkeland, Walton, and Seaborg, following Letter [Phys. Rev. Lett. 1, 18 (1958)].

ELEMENT NO. 102 †

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By the use of a radically new method[1] we have succeeded in identifying unambiguously an isotope of element 102. In other careful experiments[2] conducted over a period of many months we find that we are unable to confirm the element 102 discovery work of Fields et al. reported in 1957.[3]

The experiments at Berkeley were performed with the new heavy ion linear accelerator (HILAC) over a period of several weeks and culminated in the chemical identification of an isotope of fermium (Fm^{250}) as the daughter of an alpha-particle-emitting isotope of element

102 (102^{254}). The method used to detect the isotope of element 102 was essentially a continuous milking experiment wherein the atoms of the daughter element 100 were separated from the parent element 102 by taking advantage of the recoil due to the element 102 alpha-particle decay.

The target consisted of a mixture of isotopes of curium (95% Cm^{244} and 4.5% Cm^{246}) mounted on a very thin nickel foil. The target was approximately 0.5 mg/cm^2 thick and was covered with 75-μg/cm^2 aluminum to prevent curium "knockover". The curium was bombarded with monoenergetic C^{12} ions at energies from 60 to 100 Mev. The transmuted atoms were knocked into helium gas to absorb the considerable recoil energy. It was found that with a sufficient electric field strength practically all of these positively charged atoms could be attracted to a moving negatively charged metallic belt placed directly beneath the target. These atoms would then be carried on this conveyor belt under a foil which was charged negatively relative to the belt. Approximately half of the atoms undergoing alpha decay would cause their daughter atoms to recoil from the surface of the belt to the catcher foil (see Fig. 1). The catcher foil was cut transversely to the direction of the belt motion into five equal-length sections after a time of bombardment suited to the half-life of the daughter atom to be examined. The five foils were then alpha-pulse-analyzed simultaneously in a multiplex assembly consisting of five Frisch grid chambers, amplifiers, a single Wilkinson type "kick-sorter", and a printer. With this equipment it was easily possible to make all the desired measurements for identifying the atoms caught on the catcher foils and thus to measure the half-life of the parent of the recoiling atoms. The method was first successfully used in bombardments of Pu^{240} with C^{12} ions to identify a new isotope of element 100, Fm^{248}. It was shown to have a half-life of 0.6 minutes by analysis of the amounts of the 20-minute Cf^{244} caught on the catcher foils.

Experiments were then started which were aimed at finding a short-lived isotope of element 102. The most likely isotope of element 102 that could be detected with this method was deemed to be 102^{254} with a predicted half-life of seconds leading to the 30-minute, 7.43-Mev alpha-particle emitter, Fm^{250}. The first experiments showed that the electrostatic shielding between the target and the catcher foil was not complete enough, since some of the originally produced atoms such as Cf^{246} were found on the leading edge of the catcher foil; additional shielding reduced this problem to insignificance. In a series of experiments it was found that Fm^{250} could be collected on the catcher foils in accordance with a parent of half-life 3 seconds produced in the reaction Cm^{246} (C^{12}, 4n) 102^{254} (see Fig. 2). The excitation function for producing Fm^{250} in this manner was found to peak sharply at 70 ± 5 Mev corresponding to a (C^{12}, 4n) reaction in accordance with a recently developed method for calculation of (C, xn) reaction cross sections.[4] That the atoms collected are ejected by alpha recoil of atoms from the belt is proved by the fact that neither Cf^{246} nor Cf^{245}, which are collected in far greater amounts on the belt, are found prominently on the catchers. Chang-

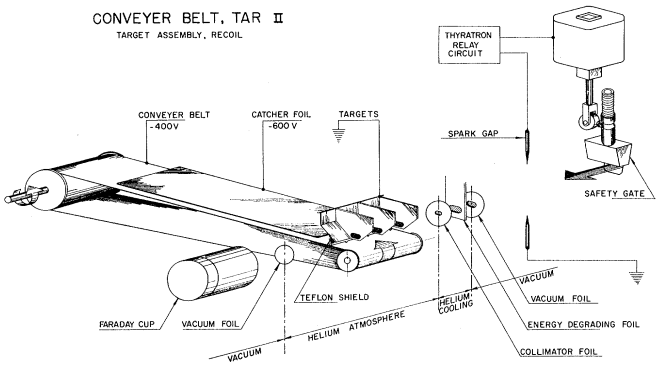

FIG. 1. Schematic diagram of conveyor belt experiment.

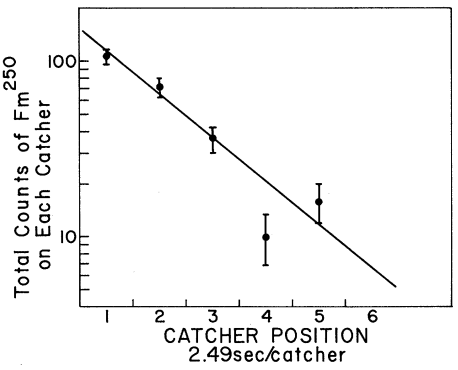

FIG. 2. Determination of half-life of 102^{254}. Data from combined results of many experiments.

ing the belt speed was found to change the distribution of the Fm^{250} on the catcher foil in a manner conforming to a three-second parent. The number of Fm^{250} counts observed in a single experiment was as great as 40 and corresponded to a maximum cross section of a few microbarns for the reaction with Cm^{246}. Nuclear emulsions placed above the moving belt to receive the alpha particles from the decaying 102 atoms are being scanned to determine the alpha energy of the 3-second 102^{254}, but there are difficulties with this method since there are hundreds of times as many tracks due to Fm^{250}, Cf^{245}, Cf^{246}, and other alpha emitters.

The final identification of the activity ascribed to Fm^{250} was carried out by dissolving the activity from the catcher foil and separating it from the other actinide elements by elution with ammonium α-hydroxyisobutyrate from a column packed with Dowex-50 cation exchange resin.[5] In one experiment 2 atoms of Fm^{250} were identified and in another 9 atoms were observed in the element 100 position (see Fig.3); there can

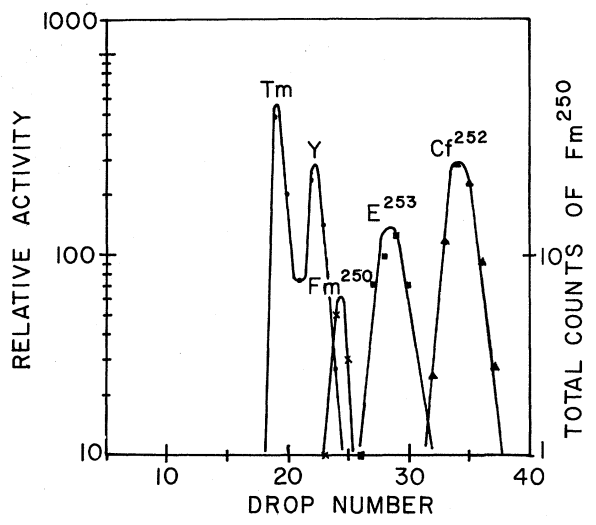

FIG. 3. Ion exchange elution curve of the Fm^{250} daughter of 102^{254}. The Tm, Y, E^{253}, and Cf^{252} activities (scale on left) were incorporated as tracers for calibration purposes.

thus be no doubt that we have identified element 102 in these experiments. We are deferring the naming of the element 102 to a later date.

We would also like to report some very recent experiments designed to look for alpha activity from as yet undiscovered element 103. The same curium target was bombarded with ca 0.3 microampere of (+7) N^{14} ions. The atoms of 103, such as 103^{256} from the Cm^{246} (N^{14}, 4n) reaction, would presumably be collected on the conveyor belt as in the other experiments. The belt speed was 3 inches per second since the half-life of an isotope such as 103^{256} would be expected to be a fraction of a second. Nuclear emulsions placed just above the belt to receive the long range alpha particles from the decay of this nuclide have been examined carefully for such corresponding tracks. We have found 16 tracks with an energy of 9±1 Mev and positions in the nuclear emulsion consistent with a half-life of approximately $\frac{1}{4}$ second. These tracks could be due to an isotope of element 103 but from these crude preliminary experiments it is of course not possible to rule out the possibility that they are due to the production of new nuclides between polonium and thorium from tiny lead or bismuth impurities or are due to prompt alpha particles produced by the interaction of neutrons with the belt material. Work is continuing in an effort to trace the source of this activity.

We are indebted to E. Hubbard and the many physicists and engineers of both Berkeley and Yale whose excellent design work have made the successful operation of the HILAC possible. The cooperation and hard work of the crew of the HILAC is gratefully acknowledged.

The engineering of the various pieces of target equipment was performed very ingeniously by C. Corum and we owe much of the success of our new methods to his excellent painstaking work. To A. E. Larsh and D. F. Mosier we extend our thanks for working out the details of the new multiplex pulse analyzer system which was the heart of our detecting system.

We would like to thank R. Garrett, C. Rossi, and J. Mahoney for their cheerful and tireless assistance in carrying out many of the operations which have provided the necessary background for the experiments which have been described. The early phases of this work were carried out with the helpful collaboration of G. R. Choppin, S. G. Thompson, T. Parsons, G. Gordon, L. Phillips, and R. Gatti.

We would like to express our appreciation to Professor C. M. Van Atta and Professor E. O. Lawrence for their continuing interest and encouragement in this research.

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*On leave from Joint Establishment for Nuclear Energy Research, Kjeller, Norway.

[1]A more detailed account by A. Ghiorso of some of these new experimental techniques is being prepared for publication.

[2]See Ghiorso, Sikkeland, Walton and Seaborg, preceding Letter [Phys. Rev. Lett. 1, 17 (1958)].

[3]P. R. Fields et al., Phys. Rev. 107, 1460 (1957).

[4]Sikkeland, Thompson, and Ghiorso, Phys. Rev. (to be published).

[5]Choppin, Harvey, and Thompson, J. Inorg. Nuclear Chem. 2, 66 (1956).

SEARCH FOR A LONG-LIVED CHARGED PARTICLE*

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Alikhanian et al.[1] have suggested the existence in cosmic rays of particles with a mass of about 500 times the mass of the electron. Their data further suggests that such particles might be long-lived, compared to the lifetime of K mesons. Keuffel et al.[2] have also suggested the possibility of the existence of such particles with lifetimes of the order of milliseconds.

A search was made for such particles using the γ-ray beam of the Cornell electron synchrotron. The detection scheme assumed the following properties of such a particle: (1) a lifetime of from 100 μsec to 1 msec; (2) that one of the charged decay products have at least the range of a 25-Mev electron; and (3) that the charge of the mass 500 particle is positive or if negative, will decay before being absorbed.

A block of beryllium 8 in. long and 4 in. by 4 in. in cross section was placed in the 1.1-Bev bremsstrahlung beam. The length of the beam pulse was 40 μsec. Two scintillation counters of dimensions 6 in. $\times$ 6 in. were placed directly at the same side of the beryllium target. Biases were set so that the counters were sensitive to minimum ionizing particles. The high voltage on the counters was pulsed off during the beam pulse, and turned on 30 μsec after the end of the beam pulse. The coincidence rate was measured as a function of time after the beam pulse. A 100-μsec lifetime was observed, which was shown to be due to background neutrons. In runs with a beam of 2×10^{11} equivalent quanta, 510 counts were observed with the beryllium target in, and 450 counts were observed with the target out. If the difference in counting rates is assumed to be due to the decay of a long-lived particle, an upper limit to the production cross section can be set.

If the mass of the particle is assumed to be $500m_e$, the particles are assumed to be produced in pairs, and the lifetime is assumed to be 150 μsec, an average upper limit to the cross section from 550 to 1100 Mev of 4×10^{-33}cm^2/nucleon can be set.

*Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

[1]Alikhanian, Shostakovich, Dadaian, Federov, and Deriagin, Zhur. Eksptl. i Teoret. Fiz. S.S.S.R. 31, 955 (1956)[translation: Soviet Phys. JETP 4, 817 (1957)].

[2]Keuffel, Call, and Sandman, Bull. Am. Phys. Soc. Ser. II, 3, 162 (1958).

ELECTRON-CAPTURE ENERGY AND LEVEL LIFETIME BY TEMPERATURE EFFECT IN Sm^{152} GAMMA-RAY RESONANCE

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Irradiating Sm_2O_3 with the Sm^{152} gamma rays that follow electron-capture in Eu^{152m} and measuring the spectral distribution of radiation scattered at 100°, Grodzins[1] has observed both the 961-kev resonance radiation and the 837-kev fluorescence. From their intensity, he deduced a mean life of $(3\pm1)\times10^{-14}$ sec. for the level. In making this estimate, he explicitly neglected effects of thermal motion; the overlap of emission and absorption frequencies is on this view due solely to nuclear recoil accompanying neutrino emission and to the distant wings of the emission and absorption lines.

We have repeated the experiment with a mean scattering angle of 90° and with somewhat different shielding arrangements. Although our counting rate was much smaller than that recorded by Grodzins, we were able to observe both lines, resonantly scattered from Sm_2O_3. We also ob-