TABLE I. The dependence of left-right asymmetry on asymmetries in the position of σ_1.

Position of σ_1	Left-right asymmetry $\times 10^2$ aluminum in σ_2	gold in σ_2
8 mm to the left	-5.5 ± 0.9	-16.1 ± 0.7
4 mm to the left	-3.35 ± 0.9	-1.0 ± 0.7
symmetric	-0.12 ± 0.5	$+5.4 \pm 0.4$
4 mm to the right	$+2.7 \pm 1.0$	$+9.5 \pm 0.8$
8 mm to the right	$+6.9 \pm 0.9$	$+9.3 \pm 0.7$

moment of the initial electron is parallel to its momentum, then, looking at σ_2 from σ_1, there will be a preferred scattering to the left for the electrons striking σ_2.

The beta emitter in the present experiment was P^{32} deposited on a thin Formvar foil. Special care was taken to eliminate backscattering since scattered electrons may reverse their polarization and mask the whole effect. For technical reasons the detectors (plastic scintillator mounted on a 5819 RCA photomultiplier) were set to accept electrons scattered at 75°. The effect is expected to be bigger for large-angle scattering.[4] The smaller angle we had to employ in the present experiment may, however, have the advantage of reducing the chances of electrons being detected after plural scattering.

About 1500 counts per minute were obtained with a 10-mC source of P^{32}. The left-right asymmetry was

$$\frac{(N_L-N_R)}{\frac{1}{2}(N_L+N_R)}=(5.4\pm0.4)\times10^{-2},$$

and in a direction which implies that the original electrons were polarized backwards (their magnetic moment pointing forwards).

Several tests were made to check whether the effect is real or due to instrumental asymmetries. Upon replacing the gold foil σ_2 by an aluminum foil of 2.4 mg/cm^2, the left-right asymmetry dropped to

$$\frac{N_L-N_R}{\frac{1}{2}(N_L+N_R)}=(-0.12\pm0.5)\times10^{-2}.$$

Since for a given polarization the left-right asymmetry increases with Z, this result is taken to indicate that everything is symmetric with respect to the plane P_1. To test this point further, the first aluminum foil σ_1 was tilted a little out of its symmetric position in both directions and the left-right asymmetry was determined for both aluminum and gold in the position σ_2. The results are given in Table I. These results indicate the sensitivity of the measurement to the exact location of the first scatterer and it is felt that they bring out the reality of the effect.

Finally, to test any possible asymmetries in the source, the same experiment was repeated with the source turned upside down (so as to obtain its mirror image in the plane P_1). The observed asymmetry was again

$$\frac{N_L-N_R}{\frac{1}{2}(N_L+N_R)}=(5.1\pm0.6)\times10^{-2}.$$

This last experiment proves directly the violation of parity conservation in beta decay.[5,6]

It is hard to have an accurate estimate of the initial polarization of the electrons from these measurements, primarily because we have as yet no energy selection for the electrons. The setup we have used recorded all electrons above 900 kev. It can, however, be seen easily that our results are compatible[4] with 100% polarization of the initial beam. The direction of polarization is unambiguous.

Further work on the energy dependence of the asymmetry, as well as other improvements, is in progress.

[1] Frauenfelder, Bobone, von Goeler, Levine, Lewis, Peacock, Rossi, and De Pasquali, Phys. Rev. **106**, 386 (1957).
[2] Goldhaber, Grodzins, and Sunyar, Phys. Rev. **106**, 826 (1957).
[3] Frauenfelder, Hanson, Levine, Rossi, and De Pasquali, Phys. Rev. **107**, 643 (1957).
[4] H. A. Tolhoek, Revs. Modern Phys. **28**, 277 (1956).
[5] T. D. Lee and C. N. Yang, Phys. Rev. **104**, 254 (1956).
[6] Wu, Ambler, Hayward, Hoppes, and Hudson, Phys. Rev. **105**, 1671 (1957).

Production of the New Element 102*

P. R. FIELDS AND A. M. FRIEDMAN, *Argonne National Laboratory, Lemont, Illinois*
AND
J. MILSTED, *Atomic Energy Research Establishment, Harwell, England*
AND
H. ATTERLING, W. FORSLING, L. W. HOLM, AND B. ÅSTRÖM, *Nobel Institute of Physics, Stockholm, Sweden*
(Received July 19, 1957)

THE work described in this communication was carried out at the Nobel Institute of Physics, Stockholm. The activity which we ascribe to element 102 was made by bombarding curium with high-energy C^{13} ions in the 225-cm cyclotron. The isotope produced was most likely either that of mass 253 or mass 251, made by the nuclear reactions:

$$Cm^{244}(C^{13},4n)102^{253} \quad \text{or} \quad Cm^{244}(C^{13},6n)102^{251}.$$

The curium, which consisted of 95% Cm^{244}, 1% Cm^{245}, 4% Cm^{246}, was deposited as a layer about 1 mg/cm^2 thick by painting from a solution of the nitrate in a mixture of acetone and amyl acetate onto a 2.7-mg/cm^2 aluminum foil about 0.5 cm^2 in area. It was bombarded in a specially designed, sealed probe with the internal beam of $C^{13(4+)}$ ions. In most experiments the majority of the ions striking the target had energies of the order of 90 Mev. The current of ions reaching the target with energies above 70 Mev was about 0.03–

0.1 μa. In a series of experiments, the energy of the carbon ions was varied through the range 65–100 Mev. Most bombardments lasted about 30 minutes. The recoiling reaction products were collected in a 1-mg/cm^2 Tygon catcher foil after passing through a 50–100 μg/cm^2 aluminum cover foil which protected the catcher foil from curium contamination.

After bombardment, the catcher foil was ignited on a platinum plate, which could be used directly as a thin source for alpha pulse analysis. In this way it was possible to commence measurement of the gross products within 3 minutes after the end of the bombardment. For chemical identification of the products, the activity was dissolved off the platinum plate and subjected to ion exchange separation procedures.

In twelve bombardments, alpha particles with an energy of 8.5±0.1 Mev were observed, and a composite decay curve of this activity (Fig. 1) gave a half-life of approximately 10 minutes. No significant spontaneous fission activity was detected.

Of the six curium targets used, only three produced recoils exhibiting the 8.5-Mev alpha activity. These three produced this product in about fifty percent of the bombardments during the first two weeks after the targets were made. After this period very few 8.5-Mev events were observed. It is believed that some of the targets were diluted by impurities so that the recoils were stopped in the target material. The reduced yield after the two-week period is attributed to radiation damage in the target and its backing by the intense alpha activity (about 0.2 curie/cm^2) and by the cyclotron beam. For these reasons the 8.5-Mev alpha activity was observed in only 12 out of approximately 50 bombardments between 70 and 100 Mev.

The 8.5-Mev alpha activity appeared in the expected element 102 position when eluted from a cation exchange column with α-hydroxy isobutyrate[1] (Fig. 2).

It was also shown that the 8.5-Mev activity appeared in the actinide position along with californium

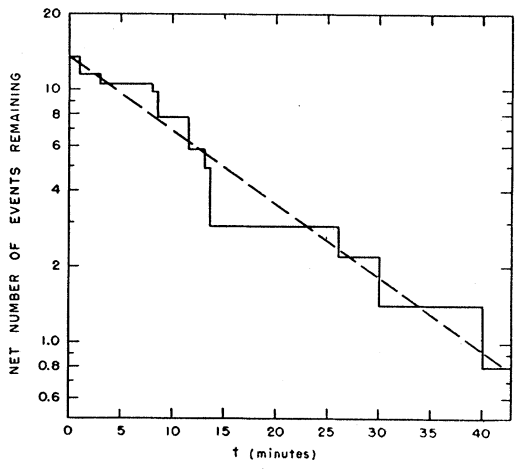

FIG. 1. Decay curve of 8.5-Mev alpha activity.

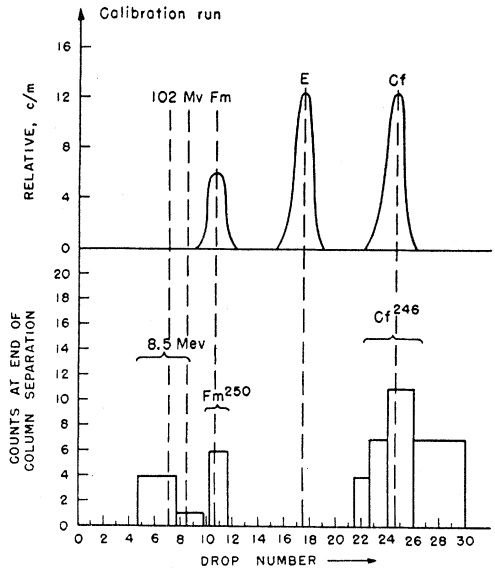

FIG. 2. α-hydroxy isobutyrate elution curve of recoil atoms from curium bombardment.

and fermium, produced in the irradiation, when eluted from a hot cation exchange column with 6N hydrochloric acid. On the basis of these experiments we concluded that the 8.5-Mev activity is due to an isotope of element 102, either directly or, possibly, as a result of electron-capture decay of a 102 isotope with a ten-minute half-life to a much shorter-lived alpha emitting mendelevium daughter. In either case, of course, the alpha activity would appear in the 102 fraction.

The predicted unhindered half-life for 8.5-Mev alpha emission from an element 102 isotope is of the order of ten seconds. Thus, even-mass isotopes with unhindered alpha decay would not be observed. The most probable isotopes are 102^{253} produced by the (C^{13},4n) reaction and 102^{251} produced by the (C^{13},6n) reaction. The low number (1–5) of 8.5-Mev alpha decays observed in a single bombardment made the statistical errors too large to determine the energy dependence of the cross section any more accurately than to limit it to one of these two reactions.

We suggest the name nobelium, symbol No, for the new element in recognition of Alfred Nobel's support of scientific research and after the institute where the work was done.

We wish particularly to thank A. B. Beadle of Harwell for his assistance in the chemical work at Stockholm and in England. We would like to acknowledge the aid of R. Barnes and Mrs. R. Sjoblom of Argonne in purifying the curium used, the aid of N. Jackson and Mrs. K. Glover of Harwell in preparing targets, and the excellent cooperation of the cyclotron crew and other members of the technical staff of the Nobel Institute in these experiments. We are grateful to Dr. W. M. Manning, director of the Chemistry

Division of Argonne, Dr. R. Spence, Head of the Chemistry Division of Harwell, Dr. H. A. C. McKay, leader of the heavy-element group at Harwell, and Professor M. Siegbahn, director of the Nobel Institute of Physics for their encouragement and interest in the research. The American and British authors would also like to thank Professor Siegbahn for the hospitality extended during this project.

* This work was performed under the auspices of the U. S. Atomic Energy Commission, the United Kingdom Atomic Energy Authority, and the Swedish Atomic Energy Commission.

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

β-γ Circular Polarization Correlation in Au^{198} and Co^{58}†

F. Boehm and A. H. Wapstra*

California Institute of Technology, Pasadena, California

(Received June 17, 1957)

THE β-γ circular polarization correlation provides a valuable tool for the study of the beta-decay interaction.[1,2] Recently a large interference term due to the presence of S and T or V and A interaction has been found in the allowed J-J transition of Sc^{46}.[3] We report here studies of the J-J transitions in Au^{198} and Co^{58}. Both nuclei exhibit a simple β-γ cascade and are, therefore, quite suitable for a circular polarization correlation experiment. The spin pattern for both decays is $2(\beta)2(\gamma)0$. Preliminary results in Au^{198} have been reported earlier.[1] In the meantime Frauenfelder *et al.*[4] and de Waard *et al.*[5] have measured the electron polarization of Au^{198}. Since the combination of the electron polarization data with our circular polarization correlation result can yield interesting information on the beta-decay coupling, improvement of our preliminary data seemed desirable. The anisotropy in the electron emission of Co^{58} has been studied by Ambler *et al.*[6] and Postma *et al.*[7] using the nuclear alignment technique. Ambler *et al.* have pointed out that their result if explained by an S, T interaction leads to a different ratio of Fermi to Gamow-Teller matrix elements than that given by Griffing and Wheatley[8] from the study of the anisotropy of γ rays from aligned Co^{58} nuclei. In the present experiment a different sign of the correlation coefficient is expected to appear.

The circular polarization of the γ rays in coincidence with the β particles was measured be using the method described in reference 1. Sources of 50–150 microcuries strength were deposited on a 0.8-mg/cm² Mylar backing. Single and coincidence counts were recorded under similar experimental conditions as described in reference 3. The relative difference in coincidence counting rate for opposite magnetic field directions is found to be, in the case of Au^{198}, $\delta=(+0.75\pm0.12)\%$, which leads to a value of $A=+0.52\pm0.09$ for the asymmetry parameter A defined in reference 1. This result is in good agreement with our earlier value. For Co^{58} the result is $\delta=(-0.27\pm0.13)\%$ and $A=-0.14\pm0.07$.

Au^{198} is a first forbidden transition. A rough analysis of our results with the help of the formulas by Alder, Stech, and Winther[2] has been carried out. Combination of the present results with the small longitudinal electron polarization found by Frauenfelder *et al.*[4] and de Waard *et al.*[5] would favor parity conservation in Fermi transitions.[9]

The result on Co^{58} is in agreement with the values corresponding to[6] $A\cong-0.20$ and[7] $A=-0.22\pm0.03$ derived from the measurements on aligned nuclei. The theoretical value for a pure Gamow-Teller transition is $A=-0.166$. If we make use of our result on Sc^{46} for the magnitude of the S, T (or V, A) interference term it seems likely that the Fermi matrix element is smaller than about $\frac{1}{4}$ of the Gamow-Teller matrix element. This is in slight disagreement with the ratio 1/2.8 found by Griffing and Wheatley.[8]

We are very much indebted to Dr. B. Stech for many helpful discussions and Professor J. W. M. DuMond for his interest in this work.

† Supported by the U. S. Atomic Energy Commission.

* On leave of absence from the Institute for Nuclear Research, Amsterdam, and the Technical University, Delft, Netherlands.

[1] F. Boehm and A. H. Wapstra, Phys. Rev. **106**, 1364 (1957).
[2] Alder, Stech, and Winther, Phys. Rev. **107**, 728 (1957); Report, University of Illinois (unpublished).
[3] F. Boehm and A. H. Wapstra, Phys. Rev. **107**, 1202 (1957).
[4] Frauenfelder, Bobone, von Goeler, Levine, Lewis, Peacock, Rossi, and De Pasquali, Phys. Rev. **107**, 909 (1957).
[5] H. de Waard (private communication).
[6] Ambler, Hayward, Hoppes, Hudson, and Wu, Phys. Rev. **106**, 1361 (1957).
[7] Postma, Huiskamp, Miedema, Steenland, Tolhoek, and Gorter, Physica **23**, 259 (1957).
[8] D. F. Griffing and J. C. Wheatley, Phys. Rev. **104**, 389 (1956).
[9] *Note added in proof.*—New measurements on Au^{198} by P. E. Cavanagh *et al.* (private communication) and C. S. Wu *et al.* (private communication) indicate, however, that the longitudinal electron polarization is nearly $-v/c$ in this nucleus. In that case our experiment agrees well with the two-component neutrino theory and indicates a maximum amount of interference between different T (or A) and S (or V) matrix elements.

Spin and Magnetic Moment of P^{32} by the Electron Nuclear Double-Resonance Technique

G. Feher, C. S. Fuller, and E. A. Gere

Bell Telephone Laboratories, Murray Hill, New Jersey

(Received July 15, 1957)

THE spin and magnetic moment of 14-day P^{32} was determined by the electron nuclear double resonance[1] (ENDOR) technique. The P^{32} obtained from Oak Ridge was diffused[2] into high-resistivity silicon plates having a total volume of 0.25 cm³.

The paramagnetic resonance signal observed at ~9000 Mc/sec and 1.2°K is shown in Fig. 1. It corre-