Radioactive Isotopes of Ga and Ge

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(Received July 19, 1948)

The radioactive germanium isotope of 1.65-day half-life has been produced by Zn(α,n), Ga(d,$2n$), and Ge(n,$2n$) reactions, but not by deuteron bombardment of germanium. This isotope is reassigned and placed at Ge^{69}. It decays with emission of positrons, x-rays, and gamma-rays. No evidence for the existence of the 195-day period has been found at Ge^{69} by deuteron bombardment of gallium. The characteristic x-ray lines of gallium from decay activity of the 11.4-day Ge^{71} have been photographed by a curved crystal camera. Deuteron bombardment of Ge^{76}, enriched electromagnetically to 70 percent, has given no evidence of a 9-day period at Ga^{74}. The half-life of Ge^{75}, produced by fast neutron bombardment of arsenic, is 1.37 ± 0.02 hours. The half-life of Ga^{67}, produced by alpha-particle bombardment of zinc, is 3.26 ± 0.02 days.

Ge^{71}

A RADIOACTIVE isotope of 11 days' half-life has been reported[1] in the germanium fraction from deuteron bombardment of both gallium and germanium and assigned to Ge^{71}. This isotope was found to decay by emitting electrons of about 0.6 Mev, and possibly by K-electron capture. No gamma-ray activity was observed. Other investigators[2] reported that they did not observe this 11-day activity in the germanium fraction.

In order to investigate further the 11-day germanium activity, gallium metal was bombarded with 10-Mev deuterons. Figure 1 shows the decay activity of the germanium fraction. An activity of 11.4 ± 0.1 days' half-life was found and measured over an interval of nine half-lives. Assignment of this activity may thus be made to Ge^{69} or Ge^{71}.

Additional information for assignment of this activity was obtained from germanium bombarded with deuterons. Figure 2 shows the decay activity of the germanium fraction. The existence of the 11.4-day period in the germanium fraction thus confirms the existence of this activity and assignment to Ge^{71}.

Decay measurements, as shown in both Figs. 1 and 2, indicate that this period decays entirely by K-electron capture. After the shorter periods had become negligible, cloud-chamber observations indicated only x-ray tracks. Figure 3 shows an aluminum absorption of the x-ray activity; any charged-particle radiation was removed by a magnetic field. A mass absorption coefficient of 34 cm^2/g is obtained, corresponding to a wave length of 1.35A. The wave-length of the gallium $K\alpha$ x-ray is 1.34A. No gamma-ray activity was observed in this period.

For further evidence of the K-capture process of decay of the 11.4-day period, an activated sample of GeO_2 from Oak Ridge was exposed to an 8-inch Cauchois curved crystal camera, having a mica crystal of 0.43 mm in thickness. During the 32-day exposure, decay measurements showed the x-ray activity to be decaying with the 11.4-day period. The film showed the presence of the Ga $K\alpha$ and Ga $K\beta$ x-ray lines. Identification was made by calibrating the film with the fluorescent K x-ray lines of Ga, Ge, As, and Se.

Ge^{69}

An activity of 30 ± 4 hours' half-life has been reported[2] in the germanium fraction from Ge(n,γ), Ge(n,$2n$), Ge(d,p), and Se(n,α) reactions. This activity was assigned to Ge^{71}. A 37-hour positron emitting activity has been found[3] in the germanium fraction from zinc bombarded with alpha-particles and assigned to

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[1] G. T. Seaborg, J. J. Livingood, and G. Friedlander, Phys. Rev. 59, 320 (1941).
[2] R. Sagane, G. Miyamato, and M. Ikawa, Phys. Rev. 59, 904 (1941).
[3] Wilfred B. Mann, Phys. Rev. 54, 649 (1938).

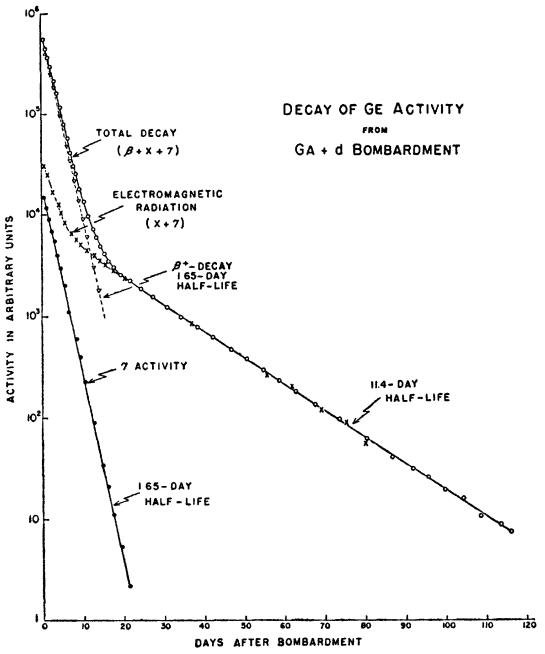

FIG. 1. Decay of Ge activity from deuteron bombardment of gallium. The 11.4-day x-ray and 1.65-day positron periods are shown.

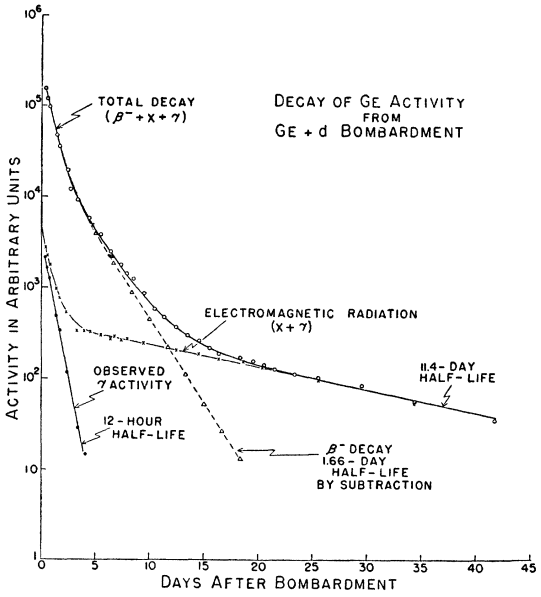

FIG. 2. Decay of Ge activity from deuteron bombardment of germanium. The 11.4-day x-ray and 1.66-day negative beta-activities are shown. The only gamma-activity present is that of the 12-hour period.

Ge^{69}. Subsequent investigators[1] reported a 40-hour activity in the germanium fraction from gallium bombarded with deuterons. This period, found to emit positrons of 1.2 Mev, was assigned to Ge^{71}. An activity of the same half-life was also produced by these workers from deuteron bombardment of germanium. They suggested that a long 195-day germanium period reported[3] in the germanium fraction from alpha-particle bombardment of zinc might possibly be due to Ge^{69}.

In order to clarify these conflicting interpretations and to determine the decay characteristics of this isotope of approximately 40 hours' half-life, a study was made of the short activity existing in the germanium fraction from deuteron bombardment of gallium.

Figure 1 shows a half-life of 1.65 ± 0.02 days, obtained over nine half-lives by subtraction of the electromagnetic radiation, $(x+\gamma)$, from the total activity, $(\beta+x+\gamma)$. This activity decays by the emission of positrons, x-rays, and gamma-rays.

Cloud-chamber observations immediately after chemical separation showed the presence of only positrons and x-rays. Aluminum absorption measurements of the positron activity, shown in Fig. 4, indicate a beta-end point of 0.433 g/cm² of aluminum, corresponding to an energy of 1.0 Mev as determined by the Sargent range-energy relation.

A lead absorption of the gamma-ray associated with the 1.65-day half-life, as seen in Fig. 5, indicates energies of 0.50 Mev and 1.22 Mev. The 0.50-Mev gamma-ray is due to annihilation radiation.

Subtraction of the γ-ray activity shown in Fig. 1 from the $(x+\gamma)$ activity indicates the

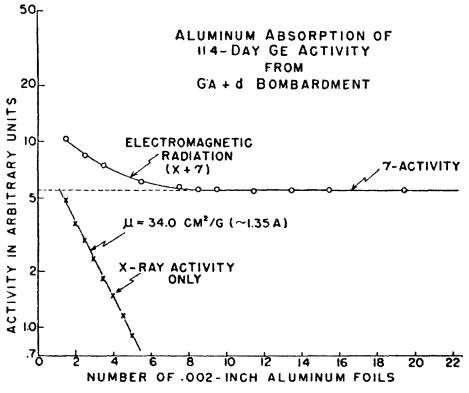

FIG. 3. Aluminum x-ray absorption of the 11.4-day x-ray period of Ge.

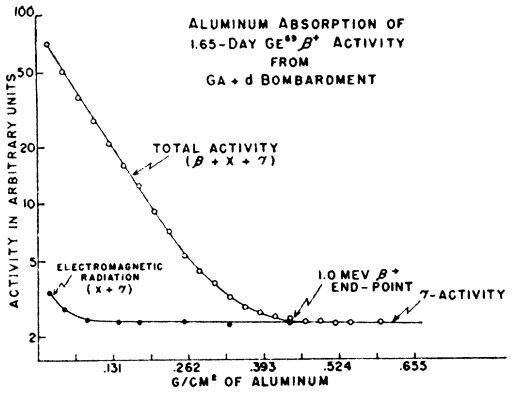

FIG. 4. Aluminum absorption curve of the 1.65-day positron activity in Ge showing 1.0-Mev end point.

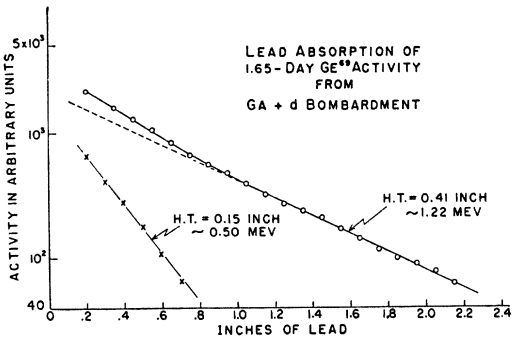

FIG. 5. Lead-absorption curve for the 1.65-day Ge^{69} period.

presence of x-rays in the 1.65-day period. From consideration of the amount of x-ray activity that would be expected from "bremsstrahlung" effect, it was concluded that this x-ray radiation was due to the K-capture process. The ratio of K-capture processes to positron emissions in the 1.65-day activity is 2 to 1. This value was obtained by multiplying the ratio of positron to x-ray activity by a factor giving the relative ionization produced by beta-radiation and x-ray radiation in the energy ranges involved.

This same positron activity of 1.65-day half-life has been produced in the germanium fraction from zinc bombarded with alpha-particles and from germanium bombarded with fast neutrons.

Figure 2 shows the existence of an activity of a similar half-life in the germanium fraction from deuteron bombardment of germanium. In this case, however, cloud-chamber observations indicated only negative beta-activity. This beta-negative emitting activity of As^{77} which is the daughter product of Ge^{77} has frequently been confused with the 1.65-day Ge^{69} activity. Since only the 11.4-day Ge^{71} has been produced by the (d,p) reaction on Ge^{70}, the positron emitting period of 1.65-day half-life in germanium therefore is assigned to Ge^{69}, and has been produced by $Ga(d,2n)$, $Zn(\alpha,n)$, and $Ge(n,2n)$ reactions.

Ge^{75}

A value of 1.48 hours has been reported[1] for the half-life of Ge^{75}, produced in the germanium fraction by fast neutron bombardment of arsenic. A small gamma-ray intensity was found associated with this activity. Other investigators[2] report a half-life of 1.37 hours and a beta-end-point energy of 1.10 Mev.

The decay activity of Ge^{75}, produced by fast neutron bombardment of arsenic, showed a single half-life activity of 1.37 ± 0.02 hours, measured over an interval of seven half-lives. No gamma-ray activity was observed.

Apparent longer half-life values of approximately 1.48 hours have also been obtained in the arsenic fractions from deuteron bombardments of germanium. This larger value is easily due to errors involved in subtraction of the longer periods.

Ga^{74}

An activity of about nine days' half-life has been reported[2] in the gallium fraction from deuteron bombardment of germanium and assigned tentatively to Ga^{74}.

In order to study the characteristics of this period, a sample of GeO_2, enriched from 6.5 percent to approximately 70 percent in isotope 76,† was reduced in a hydrogen furnace to metallic germanium, pressed into an aluminum target holder, and bombarded with deuterons. The gallium activity was chemically extracted.

No evidence of a long period in gallium was found, although the decay of this fraction indicated a certain amount of 14.1-hour Ga^{72} produced by the (d,α) reaction on the Ge^{74} isotope of reduced percentage. Hence the presence of a long period assigned to Ga^{74} seems improbable.[4]

† Supplied by the Y-12 plant, Carbide and Carbon Chemicals Corporation, through the Isotopes Division, U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

[4] U. S. Atomic Energy Commission Abstracts of Declassified Documents, Vol. 11, No. 5, MDDC—1694A, p. 125.

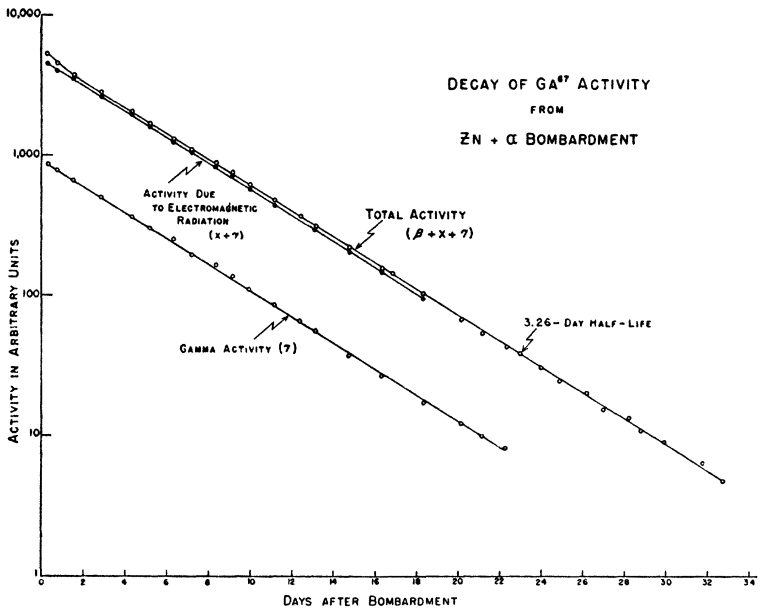

FIG. 6. Decay activity of Ga^{67} produced by alpha-particle bombardment of Hilger zinc.

Ga^{67}

A decay activity of 97 hours' half-life was first reported,[5] produced by bombardment of zinc with deuterons. No isotopic assignment was made. Later investigators[6,7] identified this period as that of Ga^{67}. From deuteron bombardment of zinc, a complete study[7] was made of the characteristic radiations of Ga^{67} activity, and its half-life was given as 83 hours.

Figure 6 shows the decay activity of the gallium fraction from alpha-particle bombardment of zinc. Since Hilger zinc was used and since a single activity was evident, the value of the half-life, determined over eight half-lives, is found to be 3.26 ± 0.02 days. Studies of the radiations emitted by this isotope are in agreement with those previously reported.[7]

[5] J. J. Livingood, Phys. Rev. **50**, 425 (1936).
[6] Wilfred B. Mann, Phys. Rev. **53**, 212 (1938). Luis W. Alvarez, Phys. Rev. **53**, 606 (1938).
[7] Luis W. Alvarez, Phys. Rev. **54**, 486 (1938).

DISCUSSION

As illustrated in Fig. 1, no evidence was found for existence of the 195-day Ge activity, reported at Ge^{69}. The production of this 195-day activity by the $Ga^{69}(d,2n)$ reaction must be less than 1/150 of the production of the 11.4-day activity by the $Ga^{71}(d,2n)$ reaction.

The relative reaction cross section for the production of the 11.4-day germanium activity by $Ga^{71}(d,2n)$ reaction to that of the 1.65-day germanium activity by $Ga^{69}(d,2n)$ is observed to be 10 to 1.

ACKNOWLEDGMENTS

The support received from the Ohio State University Development Fund and the Graduate School is gratefully acknowledged. Appreciation is also expressed to Mr. H. L. Finston and Mr. R. M. Dyer for their excellent chemical separations required in this work.