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Radioactive Arsenic Isotopes

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Simultaneous alpha-particle bombardments of Ge^{70}, enriched electromagnetically to 90 percent, and germanium of normal isotopic constituency have established the location of an arsenic activity of 76±3 days' half-life at mass number 73. Decay is by K-capture into Ge^{73}. The energy of the gamma-ray is about 0.10 Mev. The half-life of As^{74}, measured over 10 half-lives, is 17.5±0.1 days. Simultaneous deuteron bombardments of two selenium samples, enriched, respectively, in isotope 74 and 76, have established the location of the 1.08-day arsenic activity at mass number 72. A radioactive arsenic isotope of 2.08 days' half-life has been produced by deuteron bombardment of germanium and is assigned to As^{71}.

76-DAY As^{73}

In arsenic a 90-day half-life activity produced by deuteron bombardment of germanium has been reported.[1] This activity was assigned to As^{77} since negative beta-particles were thought to be emitted in the decay process. Later investigators,[2] by studying the radiations in a magnetic lens β-ray spectrometer, found a 0.052-Mev gamma-ray which was internally converted. K x-rays were also observed.

Results obtained by the last group above would indicate assignment of this activity to an arsenic isotope other than As^{77}. This statement is based on the fact that the location of As^{77} relative to stable isotopes would prohibit its decay by K-capture. The series of experiments described under this section were to establish the isotopic assignment and to study more completely the decay characteristics.

Figure 1 shows the decay activity of the arsenic fraction from deuteron bombardment of germanium. The measuring technique, which employed a Wulf Electrometer attached to a Freon-filled ionization chamber, was similar to that described previously.[3]

A half-life of 76 days is found. This activity decays entirely by emission of electromagnetic radiation. After the shorter half-lives had become negligible, cloud-chamber observations indicated no beta-activity, although x-ray ionization was observed.

Figure 2 shows an aluminum absorption of this x-ray activity. A mass absorption coefficient of 28.5 cm^2/g is obtained, corresponding to a wave-length of 1.27A. Since the wave-length of the Ge $K\alpha$ x-ray is 1.25A, it is evident that the K-capture process takes place in the activity. This is further confirmed by the decay curves in Fig. 1, where it is seen that the total activity, $(\beta+x+\gamma)$ eventually becomes equal to the electromagnetic activity $(x+\gamma)$. An aluminum absorption measurement, made with an open ionization chamber, gave no evidence of low energy beta-activity.

A copper absorption measurement of the gamma-activity of this 76-day period indicates an energy of 0.10 Mev.

In Fig. 3 is shown the presence of this same activity produced in the arsenic fraction from germanium bombarded with 20-Mev alpha-particles. The value of the half-life, measured over four half-lives, is 76±3 days.

The fact that alpha-particle bombardment of germanium does produce this activity and that the activity decays by K-electron capture indicates that assignment can be made either to As^{73} or As^{76}.

For additional information on assignment of this 76-day period, GeO_2, enriched in isotope 70 from 21.2 percent to about 90 percent,*** and an

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[1] R. Sagane, S. Kojima, G. Miyamoto, and M. Ikawa, Proc. Phys. Math. Soc. Japan **21**, 660, 728 (1939).

[2] L. Elliott, M. Deutsch, and A. Roberts, Phys. Rev. **63**, 457 (1943).

[3] W. S. Cowart, M. L. Pool, D. A. McCown, and L. L. Woodward, Phys. Rev. **73**, 1454 (1948).

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

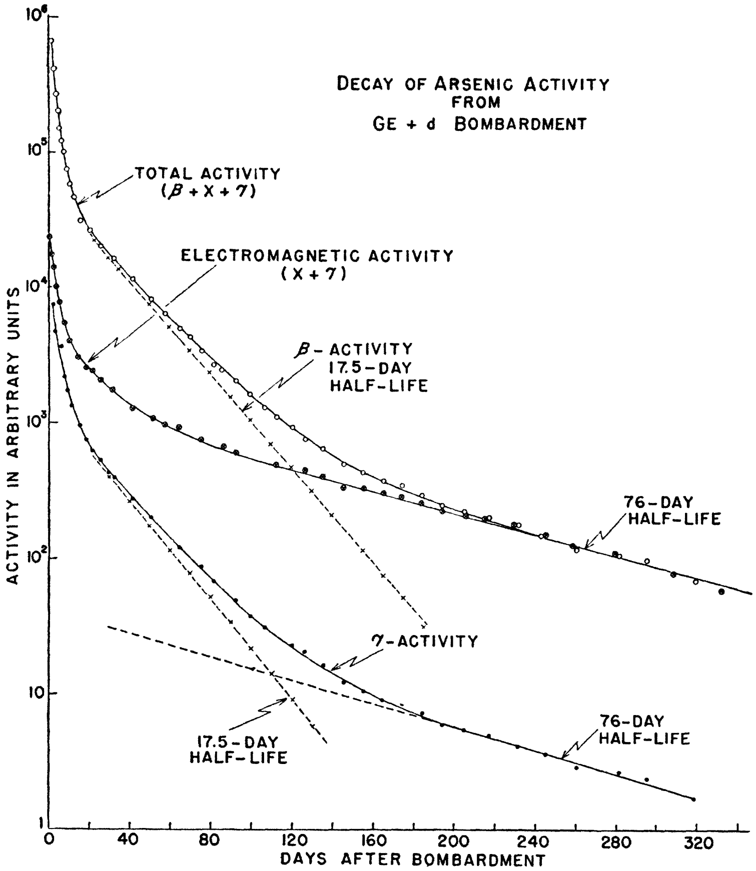

FIG. 1. Decay of As activity from deuteron bombardment of Ge. The 76-day and the 17.5-day activities are shown.

equal amount by weight of GeO_2 of normal isotopic constituency were bombarded simultaneously with alpha-particles. Decay measurements were made directly on the two activated samples.

The amount of 76-day activity appearing in the enriched Ge^{70} sample was approximately four times as great as that appearing in the ordinary Ge sample. Since stable Ge^{70} was approximately four times as abundant in the enriched Ge^{70} sample as in the ordinary Ge, it follows that this 76-day activity is produced from the stable Ge^{70} isotope. Hence the assignment of this activity, produced by the (α,p) reaction on Ge^{70}, is made to As^{73}.

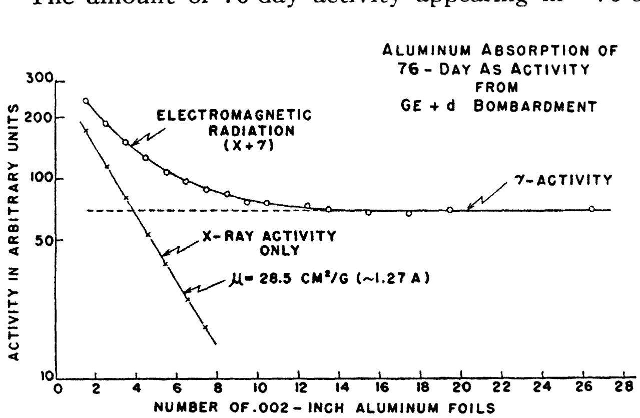

FIG. 2. Aluminum-absorption curve of the x-ray activity in the 76-day As period.

17.5-DAY As^{74}

An activity of 13.5 days' half-life has been reported[4] in arsenic, produced by fast neutron bombardment of As^{75}. This activity was assigned to As^{74}. β^+ and β^- emission were found. Other investigators[1] gave the half-life as 16 days and reported the end-point energy of the positive par-

[4] B. R. Curtis and J. M. Cork, Phys. Rev. **53**, 681 (1938).

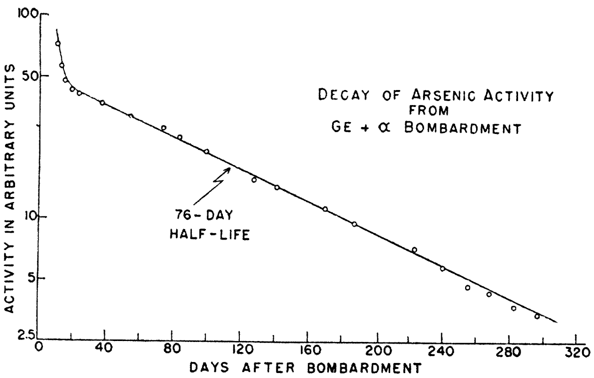

FIG. 3. Decay of As activity from alpha-particle bombardment of germanium. The value of the half-life for the long period is 76±3 days.

ticles to be 0.9 Mev and that of the negative to be 1.3 Mev.

Figure 1 shows the decay of the arsenic fraction from deuteron bombardment of germanium. The β-activity was obtained by subtraction of the electromagnetic radiation, $(x+\gamma)$, from the total radiation, $(\beta+x+\gamma)$. Subtraction of the γ-activity from the $(x+\gamma)$ activity gives no evidence of x-ray radiation. Beta-ray and gamma-energies were observed to be in agreement with values stated above.

Figure 4 shows the activity produced in the arsenic fraction from gallium bombarded with alpha-particles. Because this activity could be followed over a period of more than 10 half-lives, it is possible to assign a half-life value of 17.5 ±0.1 days.

1.08-DAY As^{72}

An investigation[5] has been made of the radiations emitted by the 1.08-day positron-emitting activity in arsenic, produced by bombardment of gallium with alpha-particles. A positron end-point energy of 2.78±0.10 Mev was reported along with a gamma-ray energy of 2.4 Mev. An alpha-particle bombardment of gallium fixes the location of this activity at As^{72} or As^{74}.

The bombardment of enriched stable Se isotopes should give sufficient information to make a mass number assignment of the activity. Two selenium samples, enriched,*** respectively, in

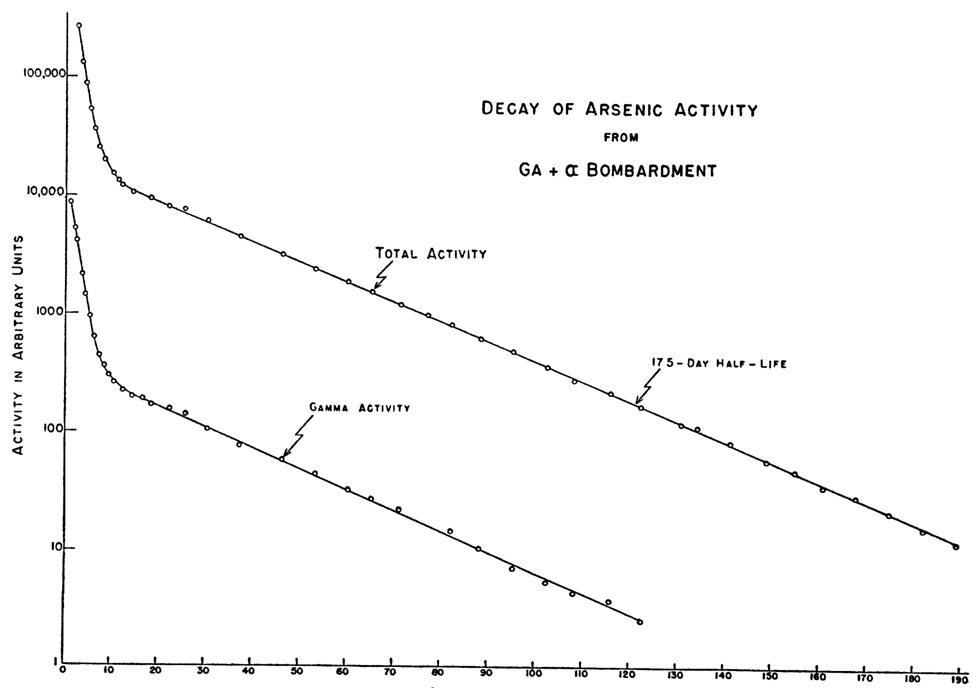

FIG. 4. Decay of As activity from alpha-particle bombardment of Ga. The value of the half-life for the long period is 17.5±0.1 days.

[5] A. C. G. Mitchell, E. T. Jurney, and M. Ramsey, Phys. Rev. 71, 825 (1947).

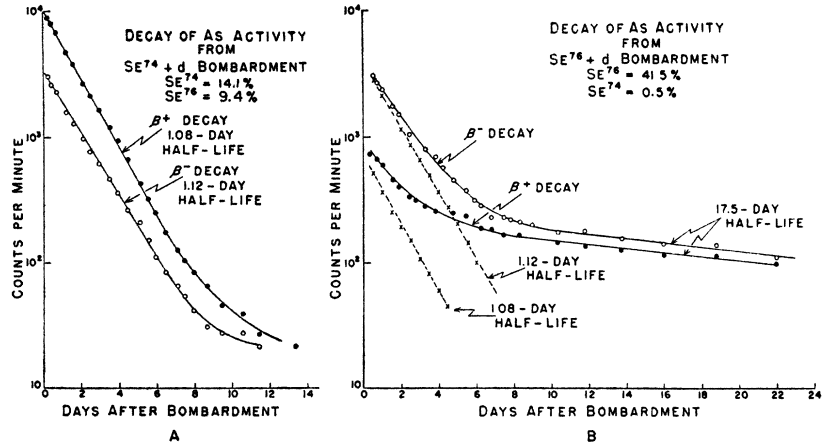

FIG. 5. A comparison of the decays of positive and negative beta-ray activities in the As fractions from deuteron bombardments of enriched Se^{74} and Se^{76}. (A) Decay of As activity from enriched Se^{74}; (B) decay of As activity from enriched Se^{76}.

Se^{74} from 0.9 percent to 14 percent and Se^{76} from 9.5 percent to 41.5 percent, were simultaneously bombarded with deuterons. A reversible electromagnetic field was used to measure[6] the positive and negative beta-decay activity of the two arsenic fractions.

Figure 5 shows these decay activities. The amount of 1.08-day positron activity in the arsenic fraction from enriched Se^{74} is seen to be considerably larger than that from enriched Se^{76}. Equivalent bombardments of the two samples are indicated by the appearance of almost identical amounts of 1.12-day As^{76} activity in both samples. This latter activity is obtained from Se^{78} by the (d,α) reaction. The amount of Se^{78} in the enriched Se^{74} sample is 21 percent and that in enriched Se^{76} is 16 percent. Since both enriched samples, Se^{74} and Se^{76}, were bombarded with equal intensity, the assignment of the 1.08-day arsenic activity therefore is made to As^{72}.

An aluminum absorption of the beta-activity indicated a beta-end-point energy of 2.8 Mev in agreement with that previously reported.

No evidence, however, was obtained of the 2.4-Mev gamma-ray energy reported above. Figure 6 shows a lead absorption measurement of the gamma-radiation in this activity. This absorption curve shows a gamma-ray of half-thickness in lead of 0.20 inch, equivalent to 0.60 Mev, and a gamma-ray of half-thickness in lead of 0.45 inch, equivalent to 1.40 Mev.

Subtraction of the γ-activity from the electromagnetic radiation, $(x+\gamma)$, indicates the presence of x-ray radiation decaying with the same period. This indicates that decay probably occurs by K-electron capture as well as by positron emission. Observations, based on the relative ionization produced by x-rays and positrons in the ionization chamber, indicate that the ratio

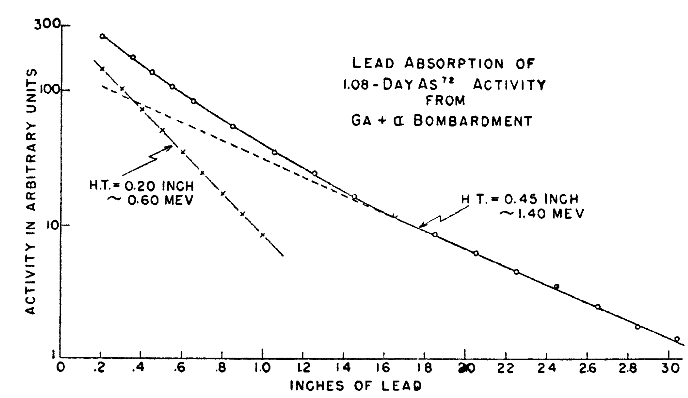

FIG. 6. Lead-absorption curve of the gamma-ray activity in the 1.08-day As^{72} period.

[6] Submitted for publication elsewhere.

of the number of x-rays to positrons emitted is approximately 2 to 1.

2.08-DAY As^{71}

A positron activity of 2.08 days' half-life in arsenic, produced by deuteron bombardment of germanium, has been reported[7] and assigned to As^{73}. The positron end-point energy was found to be 0.6 Mev.

In the investigation of the 76-day As^{73} activity, produced by alpha-particle bombardment of germanium, no evidence was found of a 2.08-day period. Calculations based on the smallest detectable intensity of the 2.08-day activity, had it been present, and the saturation intensity of the 76-day activity show that the reaction cross section for formation of the 2.08-day to that of the 76-day activity must be less than 1 to 600.

Further attempts to find this activity of 2.08 days' half-life were made by investigating the shorter periods in the arsenic fraction from deuteron bombardment of germanium. Figure 7 shows the initial part of Fig. 1 on an expanded time scale.

Subtraction of the 17.5-day beta-activity from the total composite beta-activity indicates an activity of 2.08 days' half-life, measured over approximately four half-lives.

Subtraction of the γ-activity from the electromagnetic radiation, $(x+\gamma)$, gives the net x-ray activity. By subtracting the 76-day x-ray activity from the net x-ray activity, a second x-ray period of about 11.4 days' half-life is obtained. Subtraction of this 11.4-day activity gives only one other period, one of approximately 2 days' half-life.

The presence of the 11.4-day x-ray activity, presumed to be that of Ge^{71}, would indicate that this 2.08-day activity is that of radioactive As^{71}, formed by the (d,n) reaction on Ge^{70}. The reaction cross section for formation of the 2.08-day activity to that of the 11.4-day activity is observed to be approximately 1 to 1 as would be expected if the 11.4-day activity were formed by decay of the 2.08-day activity. Hence this 2.08-day activity is assigned to As^{71}.

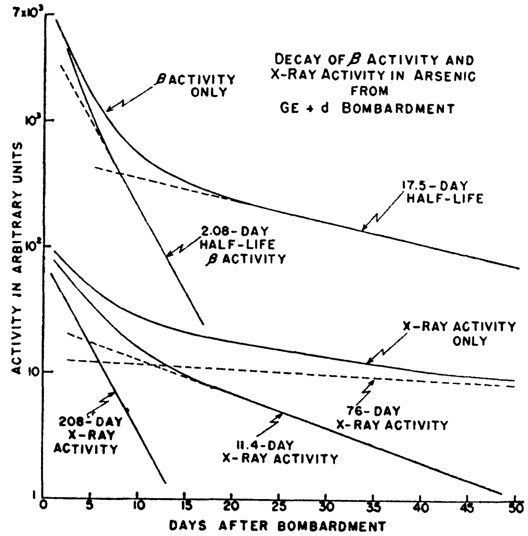

FIG. 7. The initial part of Fig. 1 showing the shorter half-life activities in the arsenic fraction from deuteron bombardment of Ge. The 2.08-day beta-ray activity, 2.08-day x-ray activity, and the 11.4-day x-ray activity are shown. Original data in Fig. 1.

This activity decays by K-capture and positron emission into Ge^{71}, then by K-capture into stable Ga^{71}. Relative intensities of x-ray activity to β-activity in this 2.08-day period indicate the ratio of K-capture to positron emission to be approximately 2 to 1.

ACKNOWLEDGMENTS

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[7] R. Sagane, G. Miyamoto, and M. Ikawa, Phys. Rev. **59**, 904 (1941).