UCRL 395
cy 2

# UNIVERSITY OF CALIFORNIA

# Radiation Laboratory

TWO-WEEK LOAN COPY

*This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545*

BERKELEY, CALIFORNIA

## DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Copy 2

UCRL-395

Unclassified Distribution

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

UNCLASSIFIED

Contract No. W-7405-eng-48

# BETA EMITTING ISOTOPES OF TIN

A. S. Newton and W. R. McDonell

July 11, 1949

Berkeley, California

| Standard Distribution | Copy Nos. |
|---|---|
| Argonne National Laboratory | 1-10 |
| Armed Forces Special Weapons Project | 11 |
| Atomic Energy Commission | 12-13 |
| Battelle Memorial Institute | 14 |
| Brookhaven National Laboratory | 15-24 |
| Bureau of Ships | 25 |
| Carbide and Carbon Chemicals Corp. (K-25 Plant) | 26-29 |
| Carbide and Carbon Chemicals Corp. (Y-12 Plant) | 30-33 |
| Chicago Operations Office | 34 |
| Columbia University (Dunning) | 35 |
| Columbia University (Failla) | 36 |
| General Electric Company, Richland | 37-43 |
| Hanford Operations Office | 44 |
| Iowa State College | 45 |
| Kellex Corporation | 46-47 |
| Knolls Atomic Power Laboratory | 48-51 |
| Los Alamos | 52-57 |
| Massachusetts Institute of Technology (Gaudin) | 58 |
| Massachusetts Institute of Technology (Kaufmann) | 59 |
| Mound Laboratory | 60-67 |
| National Advisory Committee for Aeronautics | 68-69 |
| National Bureau of Standards | 70-71 |
| Naval Radiological Defense Laboratory | 72-73 |
| NEPA Project | 74 |
| New York Operations Office | 75-82 |
| North American Avaition, Inc. | 83-84 |
| Oak Ridge National Laboratory | 85-96 |
| Patent Branch, Washington | 97 |
| Sandia Base | 98-99 |
| Technical Information Branch, ORE | 100-114 |
| UCLA Medical Research Laboratory (Warren) | 115 |
| University of California Radiation Laboratory | 116-121 |
| University of Rochester | 122-123 |
| Western Reserve University (Friedell) | 124-127 |
| Sylvania Electric Products, Inc. | 128 |
| Total | 128 |

Information Division
Radiation Laboratory
Univ. of California
Berkeley, California

# BETA EMITTING ISOTOPES OF TIN

A. S. Newton and W. R. McDonell

Radiation Laboratory and Department of Chemistry

University of California, Berkeley, California

## ABSTRACT

The $\beta^-$ emitting isotopes of tin have been investigated using deuteron bombardments of enriched Sn isotopes. The "40 minute" period has been shown to consist of two periods: a 41-min $Sn^{121}$ with a $\beta^-$ energy of about 2.5 Mev accompanied by a gamma ray of about 0.27 Mev, and a 39 minute period assigned to $Sn^{123}$ with a $\beta^-$ energy of about 1.7 Mev accompanied by a gamma ray of about 0.17 Mev and antimony x-rays. The 9.5-day period has been shown to emit a $\beta^-$ of energy 2.38 Mev, no antimony or tin x-rays, and probably no gammas. The 130 day period has been assigned to mass 123. The assignment of these and other tin periods is discussed.

# Beta Emitting Isotopes of Tin

A. S. Newton and W. R. McDonell

Radiation Laboratory and Department of Chemistry

University of California, Berkeley, California

## Introduction

Studies of the isotopes of tin have been made since 1936[1] and still the $\beta^-$ emitting isotopes are largely unassigned as to mass number. Livingood and Seaborg[1,2] bombarded Sn with 2.5 and 5 Mev deuterons and found tin periods of 9 min., 40 min, 26 hr., 10 days, ~ 70 days and 400 days. Except for the 400-day period, analogous activities were also found with slow neutron activation, but fast neutron activation failed to produce the 9-minute period. Pool, Cork and Thornton[3] had also bombarded tin with fast neutrons and found only a 47-minute period, short lived periods only being observed. Therefore the 9-minute period was assigned[2] to $Sn^{125}$ and no change has been made in this assignment since that time. In the fission of uranium, periods of 20 min, 70 min, 62 hours, 10 days, and 130 days were found.[4] The 70 minute period has been assigned

(1) J. J. Livingood and G. T. Seaborg, Phys. Rev. 50, 435 (1936).

(2) J. J. Livingood and G. T. Seaborg, Phys. Rev. 55, 667 (1939)

(3) M. L. Pool, J. M. Cork, and R. L. Thornton, Phys. Rev. 52, 239 (1937)

(4) "Nucleii Formed in Fission", Plutonium Project, J. Am. Chem. Soc. 68, 2411 (1946); Rev. Mod. Phys. 18, 513 (1946).

to $Sn^{126}$ on the basis of its decay to $Sb^{126}$,[5,6] though Seiler[7] was unable to confirm

(5) Y. Nishina, K. Kimura, T. Yasaki, and M. Ikawa, Zeits. f. Physik 119, 195 (1942).

(6) O. Hahn and F. Strassmann, Zeits. f. Physik 121, 729 (1943 ).

(7) J. A. Seiler, Plutonium Project Report CN-2126, p. 3, (Sept. 1944). NNES-PPR Vol. 9B, Paper No. 7.26.1 (1946) (to be issued).

this relationship. These results leave the 40-min., 26-hour, 62-hour, 10-day and 130-day periods to be assigned to $Sn^{121}$, $Sn^{123}$ or $Sn^{125}$, the 70-day and 400-day periods being neglected since the first is no longer observed and the second is too long to see following the 130-day period in our experiments. It is now recognized that the 26-hour and 62-hour periods are probably the same,[8,9] and this was assigned to $Sn^{121}$ by

(8) E. P. Steinberg, Private Communication.

(9) A. S. Newton, Phys. Rev. 75, 17 (1949).

Linder and Perlman[10] on the basis of deuteron bombardments of $Sn^{120}$.

(10) M. Lindner and I. Perlman, Phys. Rev. 73, 1124 (1948).

Experimental

Enriched isotopes of tin were bombarded with 14 Mev deuterons in the Crocker Laboratory cyclotron, the energy being reduced from the impinging energy of 18 Mev by placing a tantalum foil over the target. The isotopes used were obtained from the Isotopes Division of the Atomic Energy Commission which also provided isotopic analyses of the respective materials as shown in Table I.

Table I

Analyses of Tin Isotopes Used

| Mass No. \ Isotope | 120 | 122 | 124 |
|---|---|---|---|
| 112 | 1.1 ± 0.1 | 0.2 | 70.1 |
| 114 | 0.2 ± 0.1 | 0.2 | 0.1 |
| 115 | 0.1 | 0.2 | 0.2 ± 0.2 |
| 116 | 0.4 ± 0.1 | 6.3 ± 0.3 | 0.7 ± 0.4 |
| 117 | 1.1 ± 0.5 | 5.0 ± 0.2 | 5.4 ± 0.8 |
| 118 | 0.8 ± 0.1 | 10.5 ± 0.2 | 1.4 ± 0.5 |
| 119 | 1.3 ± 0.5 | 6.2 ± 0.2 | 5.3 ± 0.8 |
| 120 | $95.4^{+0.1}_{-0.2}$ | 19.2 ± 0.5 | 2.6 ± 0.5 |
| 122 | $0.2^{+0.1}_{-0.2}$ | 45.8 ± 0.1 | 1.4 ± 0.5 |
| 124 | $0.3^{+0.1}_{-0.3}$ | 7.1 ± 0.2 | 83.1 ± 3.0 |

These isotopes were obtained as $SnO_2$ and reduced to metallic tin by fusion with potassium cyanide. The pellet of metal thus obtained was melted onto a copper interceptor target and bombarded. After bombardment the tin was dissolved from the target with hydrochloric acid and bromine, a small amount of nitric acid being added when necessary to effect rapid solution. To the solution, antimony carrier was added, and the antimony plus any copper dissolved from the target was reduced to metal with iron powder. The tin in the filtrate was then oxidized to the stannic state with bromine, the acidity reduced to 1.5 N hydrochloric acid and stannic sulfide precipitated. This was dissolved in hydrochloric acid, ferric chloride carrier and sodium hydroxide added and ferric hydroxide scavenging precipitates made. Two further antimony-tin separations were made by selective sulfide precipitation. The tin was finally precipitated as metastannic acid and mounted on small watch glasses by evaporating aliquots of the slurried precipitate. This chemistry required about 1.5 hours so periods shorter than

20 minutes were not seen.

As shown in Fig. I, bombardments of $Sn^{120}$ yielded a 41-min. period, a 27-hour period, and a very small tail of an approximate 10-day period, the tail probably being due to contamination of the $Sn^{120}$ since Lindner and Perlman(10) did not observe this. Bombardments of $Sn^{124}$ with deuterons gave periods of 39 min., 9.5 days and 130 days as shown in Fig. 2. Bombardment of the $Sn^{122}$ with deuterons produced all of these periods but the two short periods were not differentiated in the mixture. In Figure 3 are plotted beryllium absorption curves of the $\beta^-$-radiation emitted by the 41 min. and 39 min. periods respectively. The 41 min. period produced from $Sn^{120}$, curve A, is seen to have a $\beta^-$ with a range of about 1260 mg/cm$^2$, an energy of about 2.5 Mev. There is a gamma ray background corresponding to about 1% of the total counting rate. The $\beta^-$ of the 39-minute period produced from $Sn^{124}$, curve B, has a range of about 800 mg/cm$^2$ of beryllium corresponding to an energy of about 1.7 Mev. It also has a gamma ray background of about 0.5% of the total counting rate. A search for x-rays associated with each of these two periods by critical absorption measurements in cadmium, silver and palladium absorbers using a beryllium-absorber-beryllium sandwich showed no critically absorbed x-rays with the 41 Mev period produced from $Sn^{120}$, but measurements on the 39 min. period from $Sn^{124}$ showed the presence of an antimony x-ray associated with it. As seen in Fig. 4, the radiation is critically absorbed by silver and palladium but not by cadmium, identifying it as an antimony x-ray. Lead absorption curves made with a beryllium-lead-beryllium sandwich of the gamma radiation from these two periods is shown in Fig. 5. Curve A shows that of the 41-min. period with a half thickness of about 1350 mg/cm$^2$ corresponding to an energy of 0.27 Mev. No x-rays are seen in this absorption curve. Curve B shows the absorption of the x-rays and gamma rays of the 39-min. period from $Sn^{124}$. The x-ray is clearly seen in the initial part of the curve being followed by a gamma ray of half thickness $\sim$400 mg/cm$^2$ Pb, a gamma energy of about 0.17 Mev. The x-ray has a half thickness in lead of about 20 mg/cm$^2$ equivalent to an energy of about 29 Kev, approximately correct for K x-rays in the antimony region. The difference in the radiation characteristics of these two periods

is great enough to make certain that they are different isotopes.

The 27-hr., 9.5 day and 130-day periods exhibited the same radiation characteristics as those described for these periods as found in thorium fission[9] and uranium fission.[4,11] No x-rays were seen with any of these periods by critical absorption

(11) G. T. Seaborg and I. Perlman, Rev. Mod. Phys. 20, 614 (1948).

measurements and the 27-hr. and 130 day periods clearly had no gamma rays associated with them. An aluminum absorption curve on the 9.5 day period indicated a gamma ray level corresponding to about 0.4% of the total radiation, low for a gamma ray unless it is largely converted, and normally too high for bremstrahlung. Lead absorption curves on this radiation indicated the possible presence of a 1.5 Mev gamma. However, a large sample of the 9.5 day period (about 1/2 millicurie) made by fission of thorium with deuterons and separated with 50 micrograms of carrier, was examined by Mr. R. W. Hayward and Prof. A. C. Helmholz on a beta ray spectrometer and no gamma ray lines found. The energy of the $\beta^-$ from a Kurie plot was found to be 2.38 Mev, with a small fraction (<10%) of lower energy $\beta^-$'s present. Coleman and Pool[12] have reported

(12) K. D. Coleman and M. L. Pool, Phys. Rev. 72, 1070 (1947).

tin x-rays to be associated with 1.25 and 9-day periods in tin, but this was not found to be the case with our 27-hour and 9.5 day activity by critical absorption measurements.

Attempts to separate an antimony daughter from either the 130-day, 9.5 day or 39 min. periods produced from $Sn^{124}$ with deuterons showed that the 130-day has no antimony daughter of half-life less than about 200 years, the 9.5 day no daughter of half-life less than 50 years and the 39 min. no daughter of half-life less than 10 years. Therefore the 2.7 yr. $Sb^{125}$ cannot be a daughter of any of these activities. The minimum half-life which would have been observed in the separations of antimony from the 10-day and 130-day periods was about 20 minutes due to the time taken for

the separations. The 39-min. had totally decayed at the time of separation of the antimony.

Approximate cross sections for the formation of these activities from the various Sn isotopes are shown in Table II. These cross sections are probably not accurate to better than a factor of 2 or 3 since chemical yield determinations were not made and in some cases the cyclotron bombardment current was known only approximately. The previous data available on deuteron cross sections with enriched tin isotopes is Lindner and Perlman's[10] value of $0.02 \times 10^{-24}$ $cm^2$ for the formation of their 28-hour period from $Sn^{120}$ with 18 Mev deuterons.

Table II

Cross Sections for Formation of Sn Activities at 14 Mev

(in units of $10^{-24}$ $cm^2$)

| Activity / Target | 27 hr. | 41 min. | 39 min. | 9.5 d | 130 d |
|---|---|---|---|---|---|
| $Sn^{120}$ | 0.016 | 0.009 | | 0.0002 ? | ---- |
| | 0.021 | 0.005 | | | |
| $Sn^{122}$ (19 Mev) | .02 | 0.08 | | 0.004 | 0.03 |
| (14 Mev) | .01 | 0.2 | | 0.007 | 0.08 |
| $Sn^{124}$ | | | 0.08 | 0.16 | 0.02 |
| | | | 0.08 | 0.1 | 0.015 |
| | | | 0.12 | 0.17 | ---- |

Bombardments of normal antimony with fast neutrons gave periods of 40 min., 27 hrs. and 130 days, the 9.5-day period not being observed. The activity was too low to run absorption curves on the 40-min. period so it is not known whether both the activities of this half-life were present. The formation of the 130-day activity in this bombardment is evidence that it can be correctly placed at $Sn^{123}$, but the absence of the 9.5 day activity is not indicative regarding assignment of this period since all isomers of a given mass number need not be produced in good yield by any

given type of bombardment. Bombardment of isotopic antimony samples with fast neutrons gave too little tin activity to evaluate due to the low flux of fast neutrons and small samples of enriched antimony available.

Discussion

From the results reported above it is apparent that the "40 minute" period is actually two periods of nearly equal half-life. The 41-min. produced from $Sn^{120}$ must be assigned to $Sn^{121}$, thus giving $Sn^{121}$ two isomers, a 41-min. period emitting a $\beta^-$ with energy of $\sim$ 2.5 Mev and a gamma ray of energy $\sim$ 0.27 Mev; and a 27 hour $\beta^-$ period of energy 0.4 Mev and no gamma[10]. It is not known whether the gamma transition between these states in $Sn^{121}$ occurs since the gamma ray absorption curve on the 41 min. period could not be carried to thick lead absorbers.

From the present data, three isomers must be placed at $Sn^{123}$; a 39-min $\beta^-$ period of energy $\sim$ 1.7 Mev accompanied by a 0.17 Mev gamma and antimony x-rays, indicating that the 39-minute period decays to an excited state of $Sb^{123}$ followed by gamma emission to the ground state, the gamma being partially converted; a 9.5 day period with a $\beta^-$ energy of 2.38 Mev and no gamma, and a 130 day period with a $\beta^-$ energy of about 1.5 Mev and no gamma.[4,11] This assignment is not very satisfactory for it is difficult to understand how the gamma transition between these states can be forbidden to such an extent. An alternative explanation placing one or more of these activities at $Sn^{125}$ would demand the existence of a longer lived isomer of the 2.7 yr. $Sb^{125}$. The assignment of these periods to mass number 123 is in accord with the cross section data reported in Table II if it is assumed that the d-p cross section for the formation of the 9.5 day period from $Sn^{122}$ is small. It is seen that in the bombardment of $Sn^{120}$, the 41-minute period which is the higher lying level is formed in lower yield than the lower lying 27-hour level. On the other hand the d-T cross sections in the bombardment of $Sn^{124}$ seem to go in the opposite direction. The 9.5 day which is the highest lying level in $Sn^{123}$ is formed in greatest yield while the 39 min. and 130 day, which are successively lower lying levels, are lower in yield in the same order. On

the basis of the isotopic abundance of $Sn^{124}$ in the $Sn^{122}$ sample, the yield of the 9.5 day period is then about the right order of magnitude.

Past attempts to study tin activities on a mass spectrograph in this laboratory have failed due to the low efficiency of ionization of tin, but it is hoped that soon the assignment of at least the 9.5 day and 130-day periods can be confirmed in this manner, which will do much to clarify the situation. The present assignable $\beta^-$ emitting tin isotopes are presented in Table III together with the known characteristics of their radiations.

Table III

Present Status of the $\beta^-$ Emitting Isotopes of Tin

| Isotope | Class[11] | Type of Radiation | Half-Life | Energy of Radiation in Mev: Particles | Energy of Radiation in Mev: $\gamma$-Rays | Produced by (See Ref. 12 for Other Reactions) |
|---|---|---|---|---|---|---|
| 120 | | Stable | | | | |
| 121 | A | $\beta^-$ | 27 hr., 28 hr.[10] 26 hr.[2] | 0.4 Abs. Al[10] | | $Sn^{120}$-d-p Sb-n-p |
| 121 | B | $\beta^-, \gamma$ | 41-min. | $\sim$ 2.5 Abs. Be | $\sim$ 0.27 Abs. Pb | $Sn^{120}$-d-p Sb-n-p ? |
| 122 | | Stable | | | | |
| 123 | A | $\beta^-$ | 130 d | $\sim$ 1.5 Abs. Al[11,4] | no $\gamma$[11] | $Sn^{124}$-d-T Sb-n-p |
| 123 | C | $\beta^-$ | 9.5 d, 10 d 11 d, 9 d[11] | 2.38 spect. | Probably no $\gamma$ spec. conv. | $Sn^{124}$-d-T |
| 123 | B | $\beta^-, \gamma$ X-Rays (Sb) | 39 min. | $\sim$ 1.7 Abs. Be | $\sim$ 0.17 Abs. Pb. | $Sn^{124}$-d-T Sb-n-p? |
| 124 | | Stable | | | | |
| 125 | B[11] | $\beta^-, \gamma$ | 10 min, 9 min[11] | $\sim$ 2.2[11] | $\sim$ 0.74[11] | Sn-d-p[11] Sn-n-$\gamma$[11] |
| 126 | D[11] | $\beta^-, \gamma$ | 70 min.[11] | 0.7 or 2.8[11] | 1.2[11] | u-n[11] |

Acknowledgements

The authors wish to express their thanks to Mr. R. W. Hayward and Prof. A. C. Helmholz for the beta-ray spectrometer runs on the 9.5 day tin and to Prof. Helmholz for valuable discussion of the problem. Thanks are also extended to Dr. J. G. Hamilton and the crew of the Crocker Laboratory cyclotron for making the bombardments, to Professors G. T. Seaborg and I. Perlman for valuable suggestions and discussions, and to Mrs. Elinor Potter for aid in counting samples.

This work was performed at the Radiation Laboratory, University of California, Berkeley, California under the auspices of the Atomic Energy Commission.

Figure 1

Decay curve of activities produced by bombarding $Sn^{120}$ with deuterons.

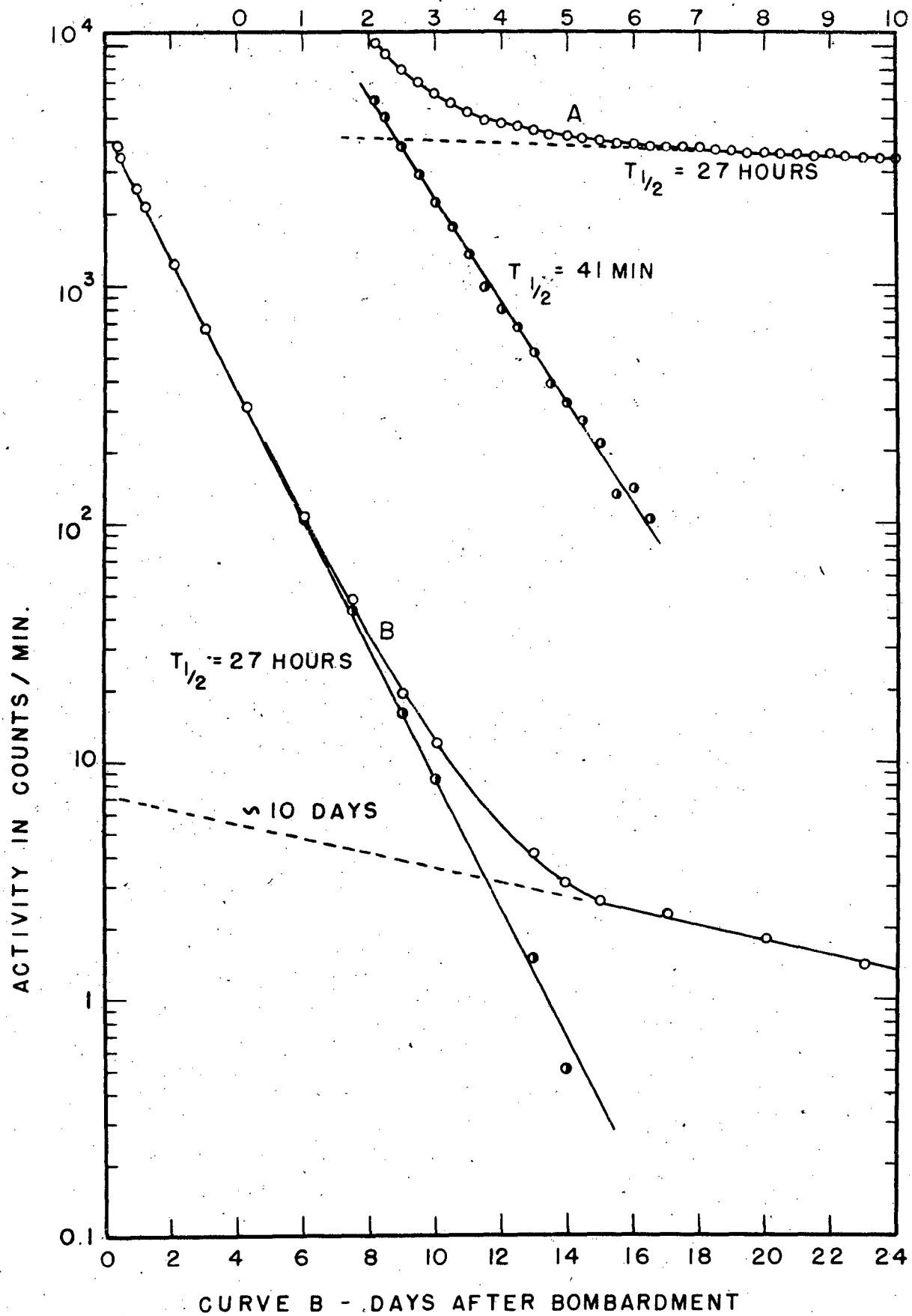
0 1 2 3 4 5 6 7 8 9 10
$10^4$
$10^3$
$10^2$
10
1
0.1
A
$T_{1/2}$ = 27 HOURS
$T_{1/2}$ = 41 MIN
B
$T_{1/2}$ = 27 HOURS
≈ 10 DAYS
ACTIVITY IN COUNTS / MIN.
0 2 4 6 8 10 12 14 16 18 20 22 24
CURVE B - DAYS AFTER BOMBARDMENT

FIG. 1

OZ 536

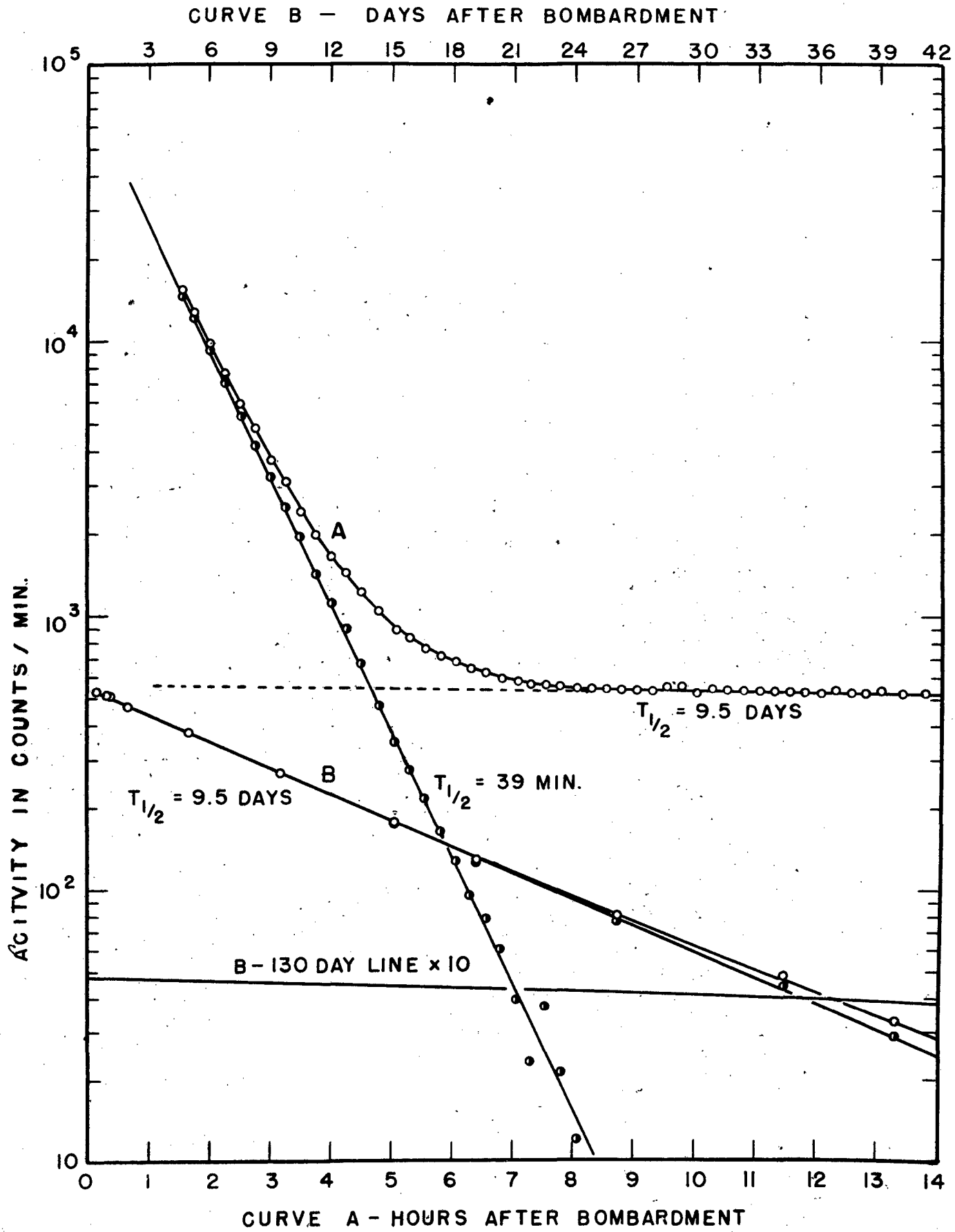
CURVE B — DAYS AFTER BOMBARDMENT
3 6 9 12 15 18 21 24 27 30 33 36 39 42
$10^5$
$10^4$
$10^3$
$10^2$
10
ACTIVITY IN COUNTS / MIN.
A
B
$T_{1/2}$ = 9.5 DAYS
$T_{1/2}$ = 39 MIN.
$T_{1/2}$ = 9.5 DAYS
B - 130 DAY LINE x 10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
CURVE A - HOURS AFTER BOMBARDMENT

FIG. 2

Figure 3

Beryllium absorption curve of beta rays from 41 and 39 minute periods in tin

Curve A - $Sn^{120}$ + deuterons, 41-minute period.

Curve B - $Sn^{124}$ + deuterons, 39-minute period.

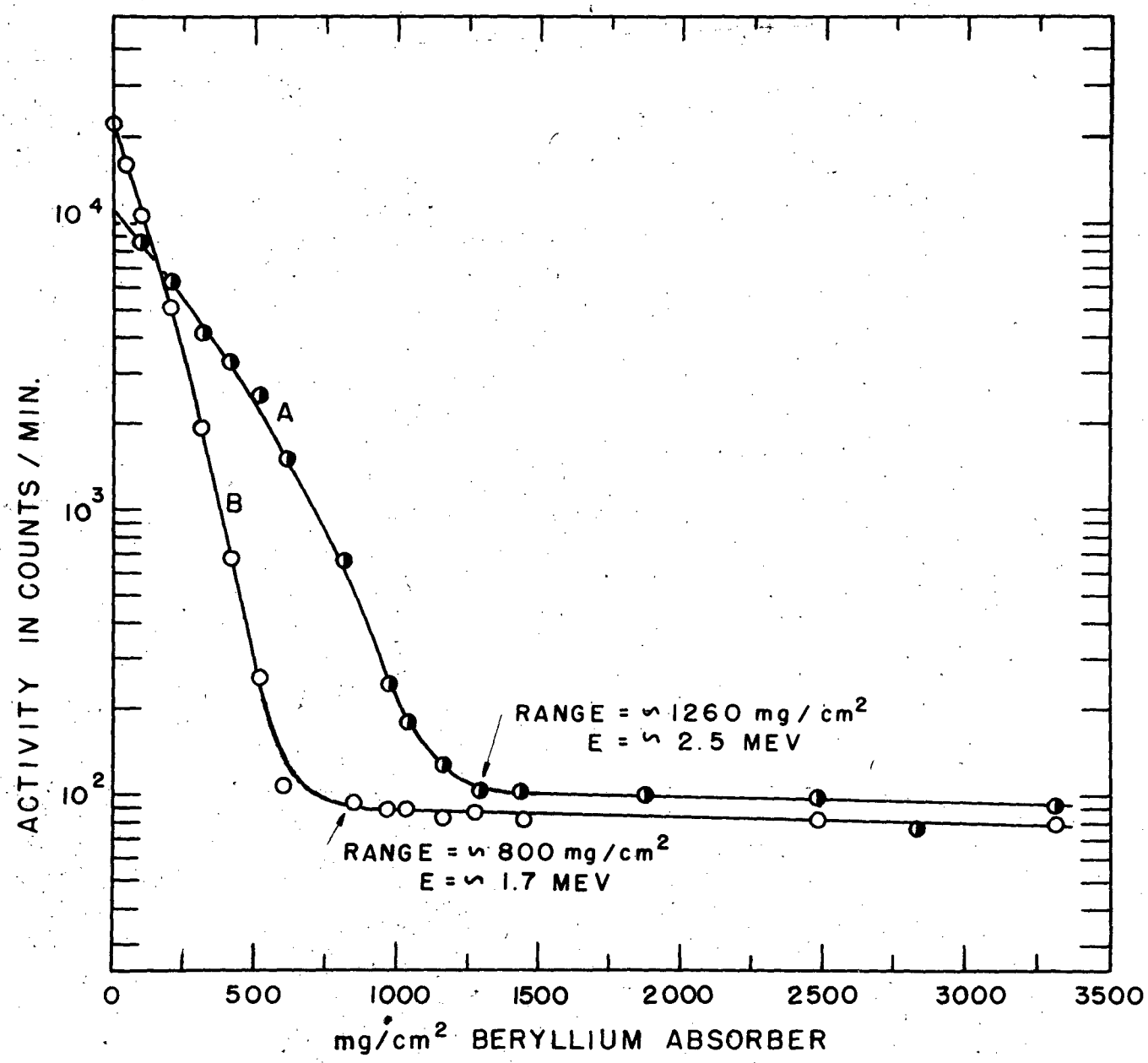
ACTIVITY IN COUNTS / MIN.
$10^4$
$10^3$
$10^2$
A
B
RANGE = ∿ 1260 mg / cm²
E = ∿ 2.5 MEV
RANGE = ∿ 800 mg/cm²
E = ∿ 1.7 MEV
0
500
1000
1500
2000
2500
3000
3500
mg/cm² BERYLLIUM ABSORBER

FIG. 3

Figure 4

Critical absorption of x-rays from 39-minute period produced by deuterons on $Sn^{124}$, showing presence of Sb x-rays.

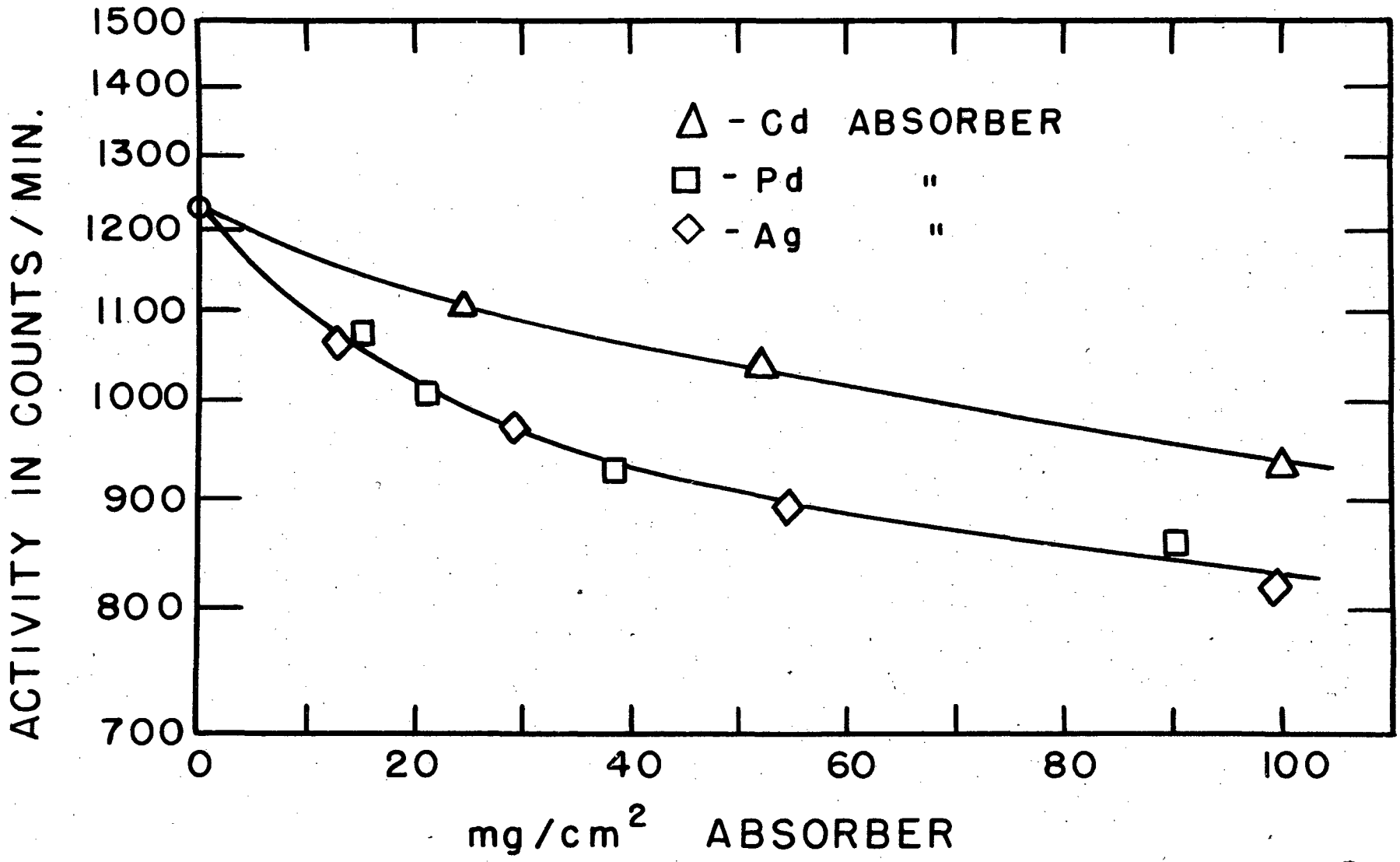
1500
1400
1300
1200
1100
1000
900
800
700
ACTIVITY IN COUNTS / MIN.
0
20
40
60
80
100
mg/cm² ABSORBER
Δ - Cd ABSORBER
□ - Pd "
◇ - Ag "

FIG. 4

Figure 5

Lead absorption curves of 41 and 39 minute periods in Sn.

Curve A - $Sn^{120}$ + deuterons, 41-minute period.

Curve B - $Sn^{124}$.+ deuterons, 39-minute period.

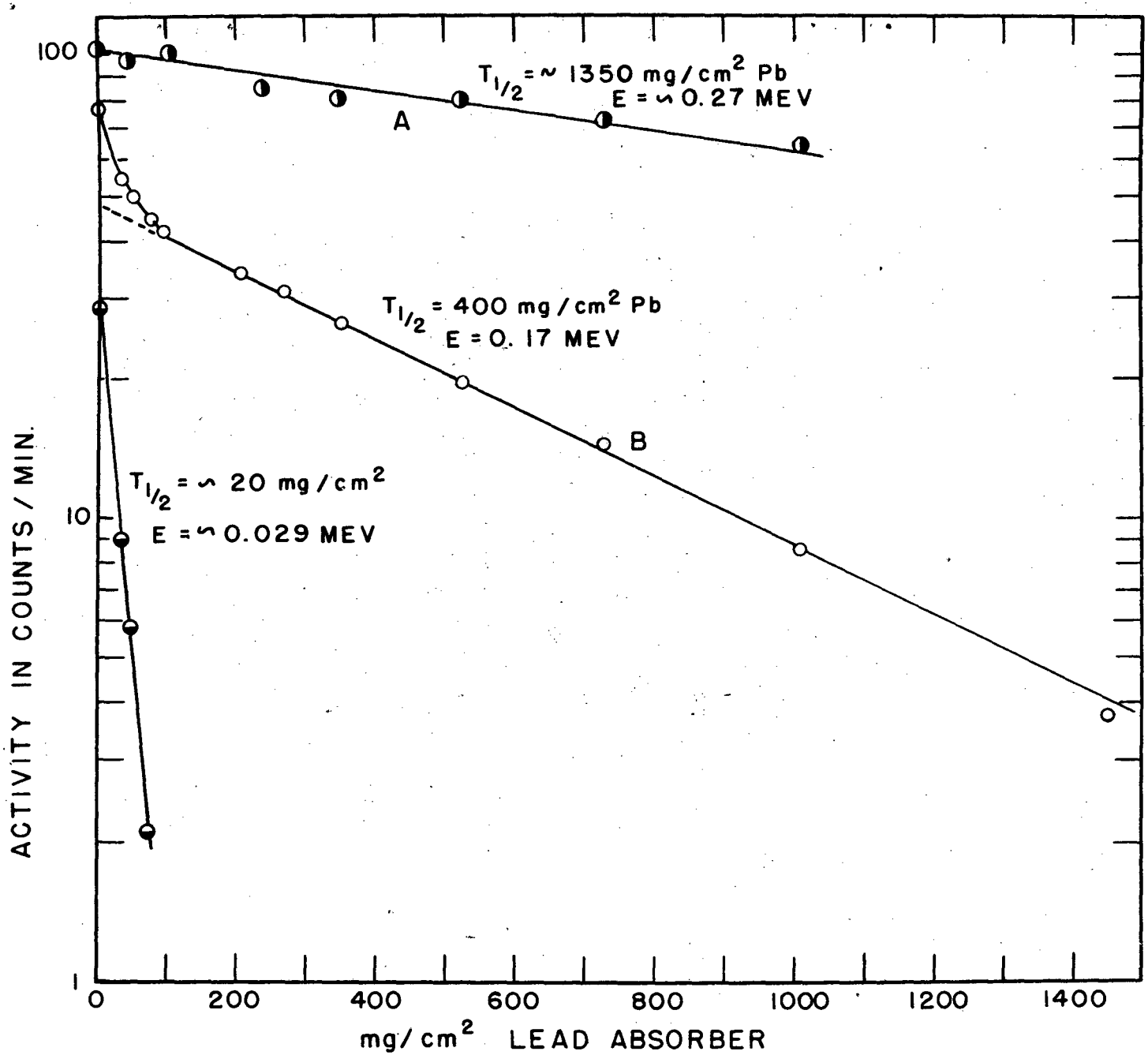
100
10
1
0
200
400
600
800
1000
1200
1400
ACTIVITY IN COUNTS / MIN.
mg/cm² LEAD ABSORBER
T1/2 = ~ 1350 mg/cm² Pb
E = ~ 0.27 MEV
A
T1/2 = 400 mg/cm² Pb
E = 0. 17 MEV
B
T1/2 = ~ 20 mg/cm²
E = ~ 0.029 MEV

FIG. 5