the 2.058-Mev level would be $d_{\frac{5}{2}}$. This assignment would be as consistent with the gamma-ray data as an $f_{\frac{5}{2}}$ assignment.

The fact that Y^{91m} does not exhibit detectable beta-emission leads to an interesting conclusion regarding the spacing of certain energy levels of Zr^{91}. The first excited state of Zr^{91} would be expected to be a $g_{7/2}$ state, and beta-emission to this level from Y^{91m} would be *allowed*. From the experimental data it is possible to to say that, if Y^{91m} does beta-decay to Zr^{91}, the intensity of the beta-transition must be less than 1.5 percent of that of the isomeric transition. From this fact and the fact that the log*ft* values of allowed transitions have an empirical upper bound of about 6.0, it is possible to calculate an upper limit on the energy of the hypothetical Y^{91m} beta-transition. This value is found to be ~0.75 Mev, which leads to the conclusion that the $g_{7/2}$ excited state of Zr^{91} is more than 1.34 Mev above the ground state. The same lower bound holds for the $g_{9/2}$ excited state. These conclusions are supported by the preliminary data of Shull and McFarland[13] on the Q values of the proton groups from the reaction $Zr^{90}(d,p)Zr^{91}$. The two proton groups they observed were found to have associated Q values of 5.03 and 2.93 Mev, suggesting that the first excited state of Zr^{91} is 2.1 Mev above the ground state.

We wish to extend our thanks to Mr. John W. Starner for his invaluable assistance with the scintillation experiments.

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[13] F. B. Shull and C. E. McFarland, Phys. Rev. 87, 216 (1952).

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Gallium-64

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A new isotope, 2.5-minute Ga^{64}, was produced by the (p,n) reaction on Zn^{64} and identified by measurement of the excitation function, by bombardment of separated isotopes, and by chemical separation. Its decay scheme includes gammas of 0.97 Mev, 3.8 Mev, and probably 2.2 Mev. The maximum energy of the principle beta is about 5 Mev. The threshold for Zn^{64} (p,n) is 8.1±0.5 Mev.

A PREVIOUSLY unidentified isotope, 2.5-min gallium 64, has been produced by bombarding zinc with high energy protons from the ORNL 86-in. cyclotron. The following tests were made to ascertain its identity.

(1) A rough excitation function for the various activities found from proton bombardment of zinc was measured by a stacked foil technique. The results, shown in Fig. 1, indicate that the 2.5-min activity has all the characteristics of a (p,n) reaction, as can be seen by comparing it with the 68-min (Ga^{68}) and 9.4-hr (Ga^{66}) activities which are known to be produced by (p,n) reactions. The ratio of the cross sections for production of the 2.5-min and 9.4-hr activities in natural zinc was found to be about 2:1 at 13 Mev, which is approximately the isotopic abundance ratio of Zn^{64} to Zn^{66}. After the excitation function was measured, all further investigation was carried out by bombarding under an absorber calculated to reduce the proton energy to 13 Mev.

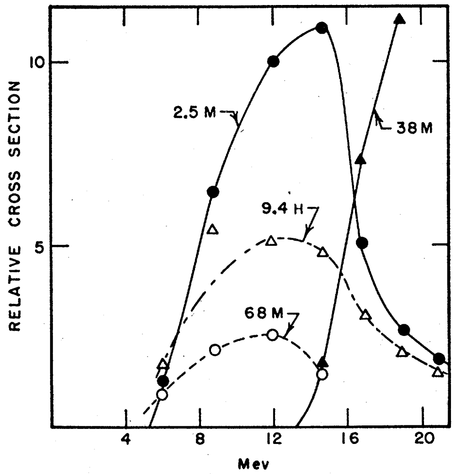

Fig. 1. Excitation functions for activities produced by proton bombardment of zinc. The 9.4-hr, 68-min, and 38-min activities are known to be produced by (p,n) reactions on Zn^{66} and Zn^{68}, and the (p,pn) reaction on Zn^{64}, respectively.

(2) A series of bombardments was made with isotopically enriched Zn^{64}.[1] This essentially eliminated the 68-min and 9.4-hr activities, but yielded very good intensities of the 2.5-min activity. Most of the spectroscopy was done with this isotopically enriched material.

(3) Chemical identification was obtained by ether extraction. The ratio of the 2.5-min to 9.4-hr activities in the ether fraction was found to be about the same as in an unprocessed zinc foil. By counting under a thick absorber to remove the 68-min activity, the decay could be followed above the 9.4-hr background through nine half-lives even after three half-lives had been con-

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[1] Separated isotopes were obtained from the Stable Isotopes Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

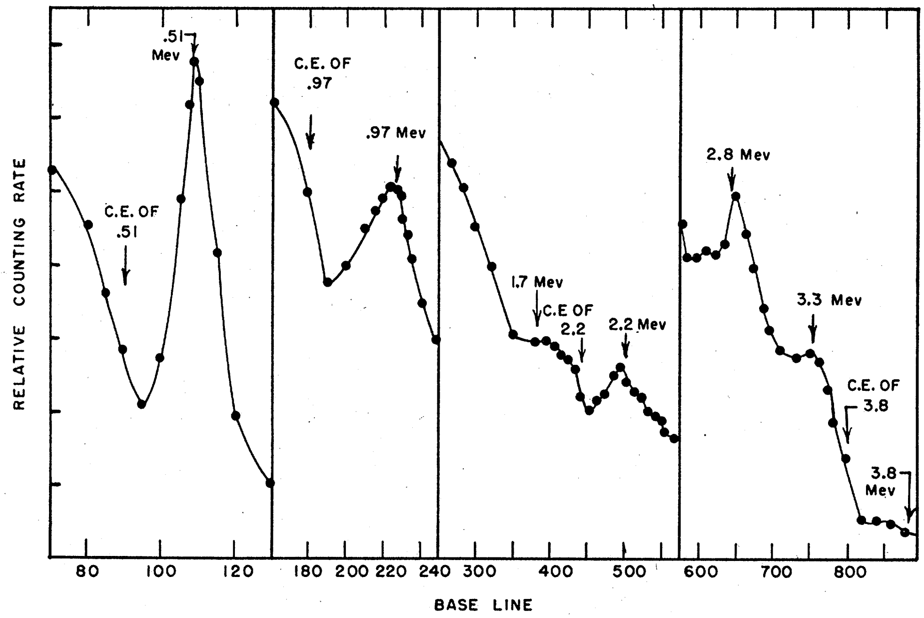

FIG. 2. Pulse-height distribution from Ga^{64} as measured with a NaI scintillation spectrometer. Various sections were obtained with different absorbers between sample and crystal. Note change in base line scale. C.E. is "Compton Edge."

sumed in removal of the target from the cyclotron and in chemical processing.

It should be noted that all isotopes, except Ga^{64}, which can be produced by (p,n) or (p,α) reactions on any of the zinc isotopes are well identified according to recent isotope tables. Both the natural zinc and isotopically enriched Zn^{64} used in the bombardments were spectroscopically analyzed and found to be free of imputities to one part per thousand.

The pulse-height spectrum of the 2.5-min activity, as obtained with a NaI scintillation spectrometer, is shown in Fig. 2. The four parts of the spectrum were obtained with different absorbers between the sample and the crystal since the large intensities necessary to obtain good statistics in the high energy portion produced total counting rates larger than could be handled by the single channel discriminator. Each point in Fig. 2 represents a three point decay curve over at least six half-lives of the 2.5-min activity. While the results of several runs differ somewhat in detail, each maximum, minimum, and edge marked in Fig. 2 was evident in every run. The low energy portion of the spectrum shows only the Compton edge and photoelectric peak of the 0.51-Mev annihilation radiation, which confirms the fact that the 2.5-min activity is a positron emitter. The next portion shows the Compton edge and photoelectric peak for a strong gamma-ray at 0.97 Mev. The highest energy portion shows a fairly definite Compton edge, the two pair peaks (at 2.8 and 3.3 Mev) and a poorly resolved photoelectric peak for what is probably a 3.8-Mev gamma-ray. The medium energy portion gives some indication of a 2.2-Mev gamma, but this interpretation should certainly be considered no more than tentative.

Considerable effort was expended in measuring the beta-ray spectrum by both the collimator and hollow crystal methods[2] with an anthracene scintillation spectrometer. Because of the difficulty in obtaining a thin and intense source, the lack of experience in handling very high energy betas with a complex spectrum, the difficulty in correcting for the gamma-ray background attributable to the short half-life, and the other well known troubles associated with beta-ray scintillation spectroscopy, only mediocre success was realized. The indications are that the most intense beta has a maximum energy in the vicinity of 5 Mev.

A relatively accurate measurement of the threshold for the $Zn^{64}(p,n)$ reaction was made by comparing the excitation function near the threshold with those of Cu^{63} and Zn^{66}, making corrections for the beam energy inhomogeneity. The Zn^{64} threshold was determined as 8.1 ± 0.5 Mev; this corresponds to a Ga^{64} maximum beta-energy of 6.4 Mev, and $\log ft > 6.1$ for the ground-state transition.

The author would like to acknowledge the very considerable help of E. L. Olson in the beta-spectroscopy.

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[2] W. H. Jordan, *Annual Review of Nuclear Science* (Annual Reviews, Inc., Stanford, 1952), Vol. 1, p. 207.