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THE DESINTEGRATION OF Ga^{73}

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THE DESINTEGRATION OF Ga^{73} * †

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ABSTRACT: The desintegration of Ga^{73} has been studied using gamma ray spectrometers, both alone and in coincidence; and by the absorption of the beta rays in coincidence with the most prominent gamma ray in the scintillation spectrometer. It was found that there were two gamma rays; one with an energy of 310 Kev and intensity of about 90% and one with an energy of 740 Kev and an intensity of about 7%. A self-consistent decay scheme is proposed showing one beta ray of 550 Kev and intensity of about 7%, one beta ray of 1300 Kev and intensity of about 83% and perhaps a third beta ray of 1600 Kev and intensity of about 10%. All the beta rays lead to the metastable state of Ga^{73}.

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I. INTRODUCTION

The decay scheme of Ga^{73} has not been the subject of a thorough investigation. The isotope was found by Siegel and Glendenin[1]. They found that it decays with a half life of 5.0 hr. and they found by absorption methods that it has one beta ray of 1.35 Mev and no gamma rays. It has also been reported[2] that it leads to the 0.53 sec Ge^{73}, the same as in decay of 76 day As^{73}. The decay of 0.53 sec. Ge^{73} has been studied by several workers[2,3,4] and it is known that it decays by the emission of two gamma rays of 53.9 Kev and 13.5 Kev the first with a conversion coefficient of about 8 and the second with a conversion coefficient greater than 1300.

We have found that Ga^{73} is followed by a gamma ray of 740 Kev with weak intensity and by a gamma ray of 310 Kev with strong intensity. The beta ray spectrum of Ga^{73} is complex and our measurements indicate that it has probably three beta ray groups. It is certain that it has two beta ray groups.

We propose a decay scheme of Ga^{73} consistent with our measurements and from this decay scheme we arrive at a value of the conversion coefficient of the 53.9 Kev gamma ray in Ge^{73}.

II. EXPERIMENTAL PROCEDURE

The Ga^{73} was prepared by irradiating samples of 15 gm of chemically pure GeO_2 in the betatron of São Paulo during one hour and at 25 cm from the target. The maximum energy of the gamma ray beam was 21 Mev. The Ga^{73} is formed by the reaction Ge^{74} (γ,p) Ga^{73}. The irradiated samples were flown to Rio de Janeiro, where the chemical processing and the measurements were done.

The irradiated GeO_2 was suspended in a small amount of water. 250 ml of 12 H HCl and 10 mg of Ga carrier were added and the mixture was boiled with continuous stirring. Another 100 ml of 12 N HCl were added and the boiling continued until the liquid was clear. All the Ge goes as $GeCl_4$. The solution was evaporated to a small volume and the samples were mounted in two different ways. For the measurements of the gamma rays, the Ga was precipitated with $K_4Fe(CN)_6$ and centrifuged in a suitable test tube to fit in the well crystal scintillation spectrometer, or the solution was evaporated to dryness at 110°C in a test tube or on a glass plate. For the measurements of the beta rays in the coincidence measurements, the concentrated Ga solution was evaporated to dryness at 110°C in plastic trays or glass plates.

The samples in the test tube were measured in a well crystal scintillation spectrometer having a NaI(Tl) crystal of 1 3/4" diameter and 2" height. The dimensions of the well are 5/8" diameter and 1 1/2" height. The spectrum showed a line of 53 ± 2 Kev and a line of 310 ± 5 Kev. Both decayed with a half life of 5 hr., showing that they were associated with the Ga^{73}. There were weaker lines at higher energy that decayed with a half life of about 14 hr. and belong to Ga^{72} which is also formed in the irradiation. In one of the measurements the total sample was divided exactly in two parts. In one of them the absolute activity of the 5 hr. beta particles was measured by the method of the well defined solid angle[5]. In the other we measured the area under the peaks of 54 Kev and 310 Kev. We calibrated the efficiency of the spectrometer as a function of gamma ray energy and so could express the areas under the peaks in absolute activity. If we express all the beta particles of 5 hr. half life as

100%, we get for the 53 Kev line 13.5± 2% and for the 310 Kev line 90 ± 15%. The energy scale of the spectrometer was calibrated with well known gamma ray lines.

We measured the spectrum of the region above 310 Kev very carefully in one experiment, following the decay of each point on the spectrum showed as a function of time. It was found that all the points of the spectrum showed a small component of 5 hr. and when this 5 hr. part was plotted as a function of energy for a given time, there was a peak at 740 ± 10 Kev. There appeared a ficticious peak at 1050 Kev, but it was shown that it was absorbed with the half thickness of Pb corresponding to 310 Kev and that it was due entirely or almost entirely to pile up of 310 Kev and 740 Kev.

We carried out measurement with two scintillation spectrometers in which we registered the counting rate of each of them and the coincidences. Both spectrometers were single channel pulse height analyzers. One of them had a NaI (Tl) crystal of 1 3/4" diameter and 2" height; the other had a NaI(Tl) crystal of 1 1/2" diameter and 1" height. They were at 1.7 cm from each other and the samples were at 1.2 cm from the first crystal. We could put absorbers between the sample and the first crystal.

The second spectrometer was set to count the line of 310 Kev. The spectrum was swept with the first spectrometer. The coincidence counts showed very well the peak at 740 Kev clean from the 14 hr. component. The pile up peak disappeared. The intensity of the 740 Kev line was measured and it turned out to be about 7% of all the beta particles.

These measurements prove the existence of at least two beta ray groups. One soft beta ray followed by the 740 Kev gamma ray and

and then by the 310 Kev gamma ray; and a harder beta ray followed by the 310 Kev gamma ray only.

We made three irradiations in which coincidence measurements were carried out between the beta rays and the 310 Kev gamma ray. The arrangement had a NaI(Tl) crystal of 1 1/2" diameter and 1 height. The crystal was operated as single channel pulse height analyzer and it was set to count the 310 Kew peak. At a distance of 2 cm from the crystal there was an end window Geiger counter and the sample was at 1.5 cm from the Geiger. Al absorbers were placed between the Geiger and the samples. The decay curve for each absorber had to be followed to correct for the 14 hr. beta activity. We registered the beta activity $N\beta$, the gamma activity $N\gamma$ and the coincidences $N\beta\gamma$. A curve of $N\beta\gamma/N\beta$ as a function of absorber thickness shows a ratio decreasing with the amount of absorber. The curve indicated that there must be a third group of beta particles. This conclusion is drawn from the fact that the two beta rays previously established were followed by the 310 Kev gamma ray.

The curve of $N\beta\gamma/N\beta$ could be fitted with a theoretical curve having 90% of the beta particles coincident with the 310 Kev gamma ray and 10% of a harder beta ray not in coincidence with the 310 Kev gamma ray. We do not regard the existence of this third beta ray as definitely established due to the cumbersome procedure of resolving decay curves of 5 hr. and 14 hr. from which its existence was inferred. Measurements of the beta ray spectra of Ga^{73} will settle this point.

The average energy of the beta ray was determined by measuring their absorption coefficient in Al as a function of absorber thickness and gives 1.3 Mev. A curve of measured absorption coefficients as a function of maximum beta ray energy was obtained using standard beta ray sources. It follows that the energy of the main beta ray is 1.3 Mev.. The energy of the softer beta ray is 0.55 Mev. and the energy of the harder beta ray is 1.6 Mev.

III. DISCUSSION

The spin and parity of the ground state of Ga^{73} is kmown to be 9/2+. The sequence of the gamma rays of 53.9 Kev and 13.5 Kev seems to be well established[4,6] and it gives for the corresponding states the choice of spins and parities given by Welker et al[3]. The spin and parity of Ga^{73} must be $3/2^-$ from shell model considerations. The three beta rays give log ft. values corresponding to allowed transitions. All these enable us to construct the decay scheme shown in Fig. 1. The spin and parity of the two upper levels of the Ge^{73} that we have found as a result of this work must be $1/2^-$, $3/2^-$ or $5/2^-$. With the information available it is not possible to decide among them.

The only discrepancy present in this decay scheme comes from the measurement of the internal conversion coefficient of Welker et al[3] for the 53.9 Kev line. Using their value of 4.7 we find that the line has an intensity of 77%. In order to get the intensity of 100% that it should have according to the decay scheme proposed, its conversion coefficient should be 6.4. The 13.5 Kev line does not show in our measurements because its large conversion coefficient and the soft electrons would not come out from our relatively thick sources.

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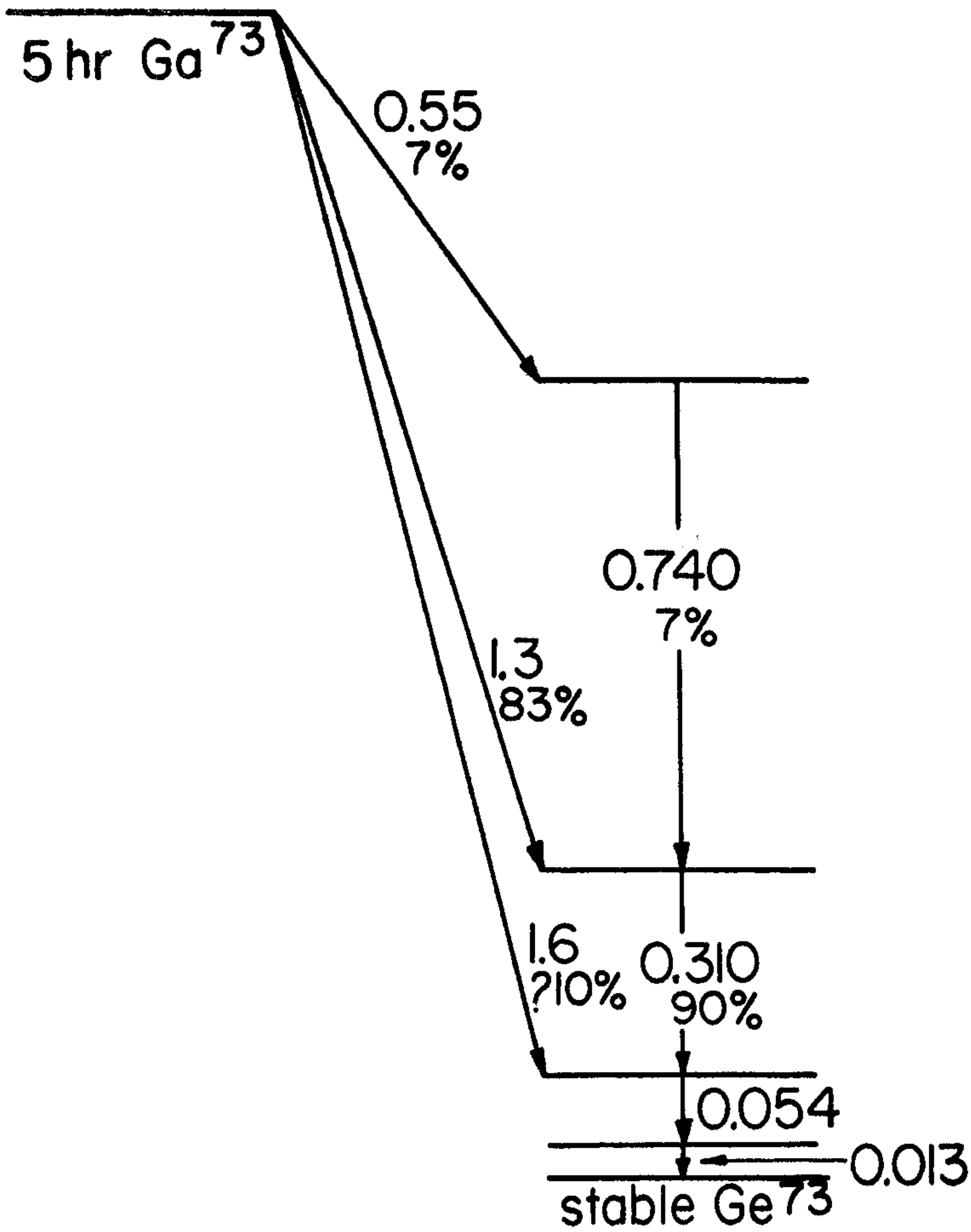

FIG. 1