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Level Structure of Ga^{66}[†][*]

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The excited levels of Ga^{66} have been investigated from the decay of Ge^{66} with high resolution Ge(Li) and Si(Li) detectors and with standard scintillation counters. Ge^{66} was produced by the (α, $2n$) reaction on enriched Zn^{64}. A chemical separation for Ge was performed. γ rays of the following energies (in keV) and intensities have been assigned to the decay of Ge^{66}: 44.3±0.5 (70), 65±0.5 (17), 91±0.5 (2), 109.3±0.5 (43), 125±0.5 (1), 148±0.5 (1), 155±0.5 (<1), 168±1 (%1), 182±0.5 (26), 190±0.5 (25), 234.5±1 (<1), 246±0.5 (24), 272±0.5 (40), 291±1 (1), 303±1 (10), 324±1 (<1), 338±1 (22), 382±1 (100), 414±1 (2), 428±1 (2), 471±1 (43), 493±1 (3), 537±1 (25), 574±1 (1.5), 595.5±1 (2.5), 638±1 (3.5), 661±1 (2.5), 705±1 (21), 756+1 (5), 821±1 (~1), and 865±1 (3) keV. The use of two Ge(Li) detectors in coincidence studies has revealed the presence of several previously unreported transitions. Based on these results, a consistent level scheme of Ga^{66} is given. The spin and parity assignments of some of the low excited levels of Ga^{66} are discussed. The half-lives of the 44.3- and 109.3-keV levels have been measured by delayed coincidence to be $(12\pm1)\times10^{-9}$ sec and $(1.2\times0.2)\times10^{-9}$ sec, respectively.

I. INTRODUCTION

PREVIOUSLY, the decay of the 2.2-h Ge^{66} has been studied by various groups of investigators.[1–3] Hopkins and Cunningham[1] in 1948 first reported a half-life of 2.5 h for Ge^{66}. No other information was given in this preliminary investigation. The level scheme as shown in the *Nuclear Data Sheets*[4] was presented by Ricci *et al.*[2] These authors, using NaI(Tl) detectors, reported a level scheme for Ga^{66}, as well as several γ rays which could not be fitted into their decay scheme. With the availability of high-resolution solid-state counters, the present work proposes to reexamine the decay of Ge^{66} to establish a level scheme of Ga^{66} with good energy determination. Moreover, the use of two Ge(Li) detectors in coincidence studies and a PDP-8/I computer programmed as a 1024-channel analyzer made accurate γ-ray energy determination possible and revealed the presence of several previously unreported transitions.

II. SOURCE PREPARATION

Sources of Ge^{66} were produced by bombarding enriched Zn^{64} (oxide) (99.9% enriched) with 40-MeV α particles from the Yale Heavy Ion Accelerator. The energy of the α particles was chosen in order to avoid any (α, $3n$) products. The bombardment time used was 90 min. After cooling the Zn target for 2 h, the following chemical separation was performed. The irradiated Zn target was dissolved in a few drops of $6N$ HNO$_3$. Then 2 mg of gallium hold-back carrier (1 mg/ml) and 3-mg Sb (3 mg/ml) were added. The solution was evaporated to near dryness, cooled, and the residue was transferred with $6N$ HCl solution to a centrifuge tube. H$_2$S was passed through to precipitate antimony sulfide and coprecipitate the Ge as a sulfide. Sb was chosen as a carrier because of the quick formation of an easily centrifugable sulfide. The Sb-Ge sulfide precipitate was centrifuged, digested with $6N$ H$_2$S-saturated sulfuric acid, filtered, washed with water and alcohol, and dried. These sources were used for our γ-ray measurements. Immediately after the chemical separation no Ga activities were observed, indicating that this Ge-Sb coprecipitation method is an extremely clean and fast procedure for obtaining Ge sources.

Bombardments of natural Zn targets were also performed; however, the produced contamination of long-lived Ge^{69} ($40h$) in the sources interfered seriously with our study, especially in the energy region 800–1200 keV. Therefore, in all measurements enriched Zn^{64} (99.9% enriched) was used.

III. EXPERIMENTAL RESULTS

A. γ-Ray Singles Spectra

γ-ray studies were carried out using 3-in.×3-in. NaI(Tl) scintillation counters and high-resolution Ge(Li) detectors. Since some of the γ rays are unresolved in NaI(Tl) spectra, the energy and intensity values (above the 50-keV region) adopted in this paper were all taken from data obtained with Ge(Li) detectors. However, whenever possible, NaI(Tl) data were also used to confirm these findings.

Figure 1 shows a typical spectrum of low-energy γ rays of Ge^{66} as seen with a 25-cm^3 Ge(Li) detector. The detector had a system resolution of 3.3 keV and peak-to-Compton ratio of 14:1 for the 1.33-MeV Co^{60} peak. The spectrum was recorded using a PDP-8/I computer as a 1024-channel analyzer in the double-precision mode and a 4096-channel analog-to-digital converter. The energy calibration was performed in

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[*] Part of this work was presented in Bull. Am. Phys. Soc. **13**, 1427 (1968), abstract DD12.

[1] H. H. Hopkins, Jr., and B. B. Cunningham, Phys. Rev. **73**, 1406 (1948); H. H. Hopkins, Jr., *ibid.* **77**, 717 (1950).

[2] R. A. Ricci, R. K. Girgis, and R. Van Lieshout, Nucl. Phys. **21**, 177 (1960).

[3] Y. Vrzal (private communication); and abstract in Bulletin of Nuclear Physics, 1968 (in Russian, unpublished).

[4] *Nuclear Data Sheets*, compiled by K. Way *et al.* (U.S. Government Printing Office, National Academy of Sciences—National Research Council, Washington, D.C., 1959), NRC B2-6-45.

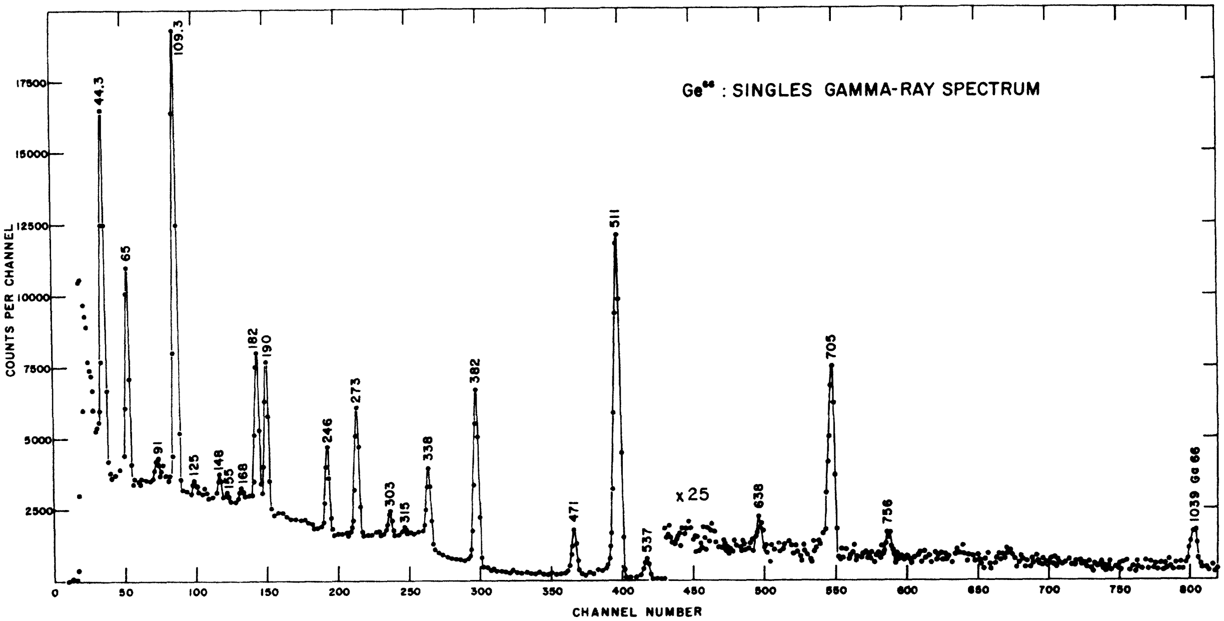

FIG. 1. Low-energy γ-ray spectrum from Ge^{66}, taken with a 25-cm^3 Ge(Li) detector.

each run using standard sources of Bi^{207}, Ba^{133}, Co^{60}, Cs^{137}, Na^{22}, and various high-energy lines of Ga^{66} which were present in the source after Ge^{66} decayed to Ga^{66}. Figure 2 shows the high-energy side of the spectrum taken with a 25-cm^3 Ge(Li) detector. The photopeaks at 185, 270, and broad 511 keV as seen in NaI(Tl) have been resolved into groups of (182, 190), (246, 273), and (471, 493, 511) keV, respectively. No γ ray was observed above 865 keV using chemically separated sources, although special efforts were made in order to find any high-energy transitions belonging to the decay of Ge^{66}.

The intensity of the various γ rays above 50 keV were obtained from the spectra taken with the Ge(Li)

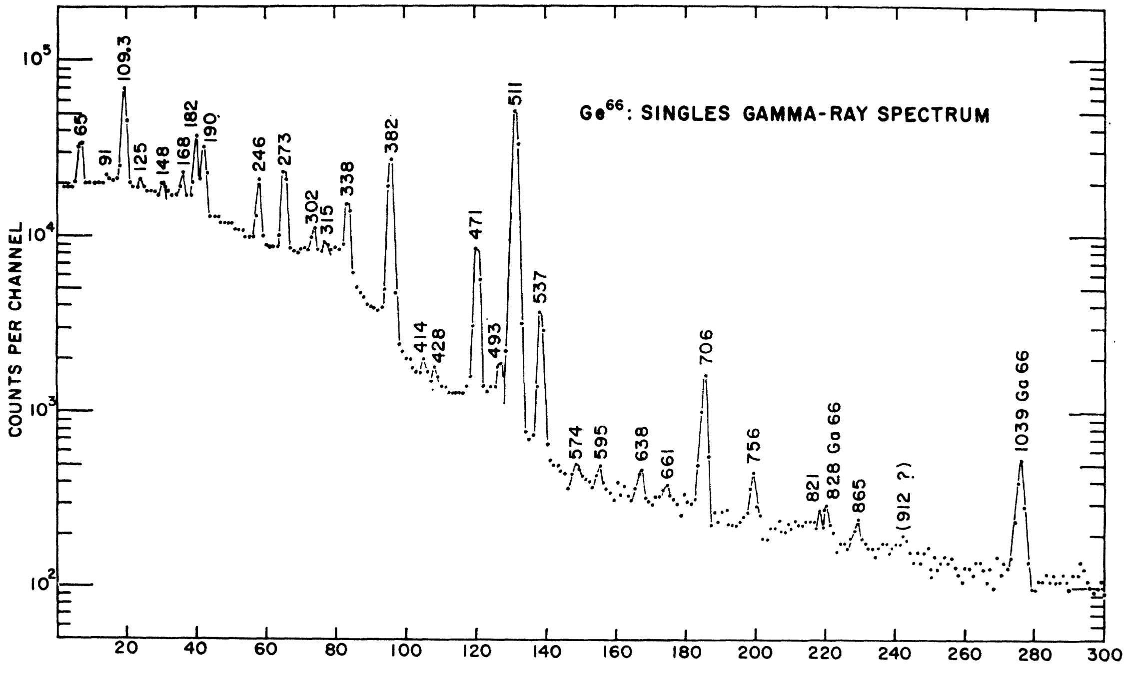

FIG. 2. High-energy γ-ray spectrum from Ge^{66}, taken with a 25-cm^3 Ge(Li) detector.

detector. Because of the window thickness, the detector dead layer, etc., the detection efficiency for the low-energy γ rays was poor, and the energy was sensitive to the relative geometry between the source and the detector. Therefore, the intensity of the 44.3-keV line was obtained using a 2-in.×2-in. NaI(Tl) detector. A list of γ-ray energies and their relative intensities is given in Table I. The energies and relative intensities assigned are the mean values obtained from a number of different measurements recorded at different times, different system gains, and with two (25-cm^3 coaxial and a 16-cm^3 planar) Ge(Li) detectors. The corresponding errors in energies are based on the errors obtained by calibration with the standard sources. The relative peak intensities were calculated from a number of runs. The errors in the relative intensities include estimated uncertainties in the backgrounds and the relative photopeak efficiency curves for the Ge(Li) detectors, which were obtained in two ways: First, a set of standard γ-ray sources whose relative intensities had been measured with NaI(Tl) detectors were used. Second, a set of points was obtained from the sources emitting several γ rays whose relative intensities were known from well-established decay schemes. The efficiency curves resulting from the separate methods were in very good agreement.

In Table I, all the γ rays which have been identified with the decay of Ge^{66} are given. The criteria for the identification was based on the half-life of 2.2 h associated with the decay of Ge^{66}. For example, the (166–168) keV line at first decays with a short half-life of 19 min previously assigned to Ge^{67},[5] and then follows a half-life of 2.2 h (Ge^{66}). The γ rays of 828 and 1039 keV belong to Ga^{66} (9.5 h).

B. Coincidence Measurements

From Figs. 1 and 2, it is evident that owing to spectral complexities it is essential to use two Ge(Li) detectors for the coincidence measurements. On the other hand, in using Ge(Li) detectors limitations are imposed by the rapid drop in counter efficiency with increased γ-ray energy. In the present coincidence studies, a 16-cm^3 planar Ge(Li) detector was employed to select the gate. The spectrum was analyzed using the 25-cm^3 Ge(Li) detector. Both the detectors were placed at 90° to each other with sufficient lead in between to prevent Compton scattering. The ratio of the coincidence counts to random counts was always kept greater than 30. No corrections due to Compton continua have been made in these data. The resolving time of the coincidence circuit used was $2\tau = 100$ nsec. For coincidence measurements, the chemical separation of Ge was performed after 90 min of the end of bombardments. Hence, some Ge^{67} as identified by the presence of 167-keV γ ray was present at the beginning.

TABLE I. Ge^{66}: γ-ray energies and their relative intensities.

γ-ray energy (keV)	Relative intensity	γ-ray energy (keV)	Relative intensity
44.3±0.5	70±5	338±1	22±3
65±0.5	17±5	382±1	100
91±0.5	2	414±1	2±2
109.3±0.5	43±3	428±1	2±2
125±0.5	1	471±1	43±4
148±0.5	1	493±1	3
155±0.5	1	537±1	25±3
168±1	1	574±1	1.5±2
182±0.5	26±3	595.5±1	2.5±2
190±0.5	25±3	638±1	3.5±1
234.5±1	<1	661±1	2.5
246±0.5	24±3	705±1	21±4
273±0.5	40±3	756±1	5±2
291±1	1	821±1	1
303±1	10±2	865±1	3±1
324	1		

Figure 3 shows the three spectra (a)–(c) which were measured in coincidence with the 44.3-, 65-, and 109.3-keV γ rays, respectively. Each source was counted for a period of 90 min after the end of chemical separation and then rejected. This eliminated any high contamination of Ga^{66} growing from the decay of Ge^{66}. Figures 4–6 show some of the Ge(Li) coincidence spectra taken with other chosen gates.

Table II shows the results of the various γ-γ coincidences. The relative intensities of the strong peaks in each spectrum were determined. For this the coincidence spectra were normalized by correcting the coincidence rates for the detection efficiencies. The intensity of the 44.3-keV line in these spectra gives the only indication as to whether the coincidence is true or not. In these spectra, at the high energy side (>800 keV), failure to observe a coincidence may be in some cases due to poor statistics or to the interference of the Ga^{66} positrons. Hence, in Table II we have left some blanks to indicate that a coincidence either has not been observed or has been ruled out.

From Fig. 3 it is evident that the 44.3-keV transition is in coincidence with the 65-, 190-, 338-, 493-, and 638-keV γ rays. The coincidence of the 109.3-keV transition gives γ rays of 125, 182, 246, 273, 428, 573, 595.5, and 756 keV. This leads to the proposal of levels in Ga^{66} at 44.3, 109.3, 234.5, 291, 382, 537, 682, 705, and 865 keV. Low-lying levels at 46 and 114 keV have been well established from previous experiments by Ricci *et al.*[2] The higher-energy coincidences reported in Figs. 4–6 confirm the above levels in Ga^{66}. These levels

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[5] H. Bakhru and I. M. Ladenbauer-Bellis, Phys. Rev. **177**, 1686 (1969).

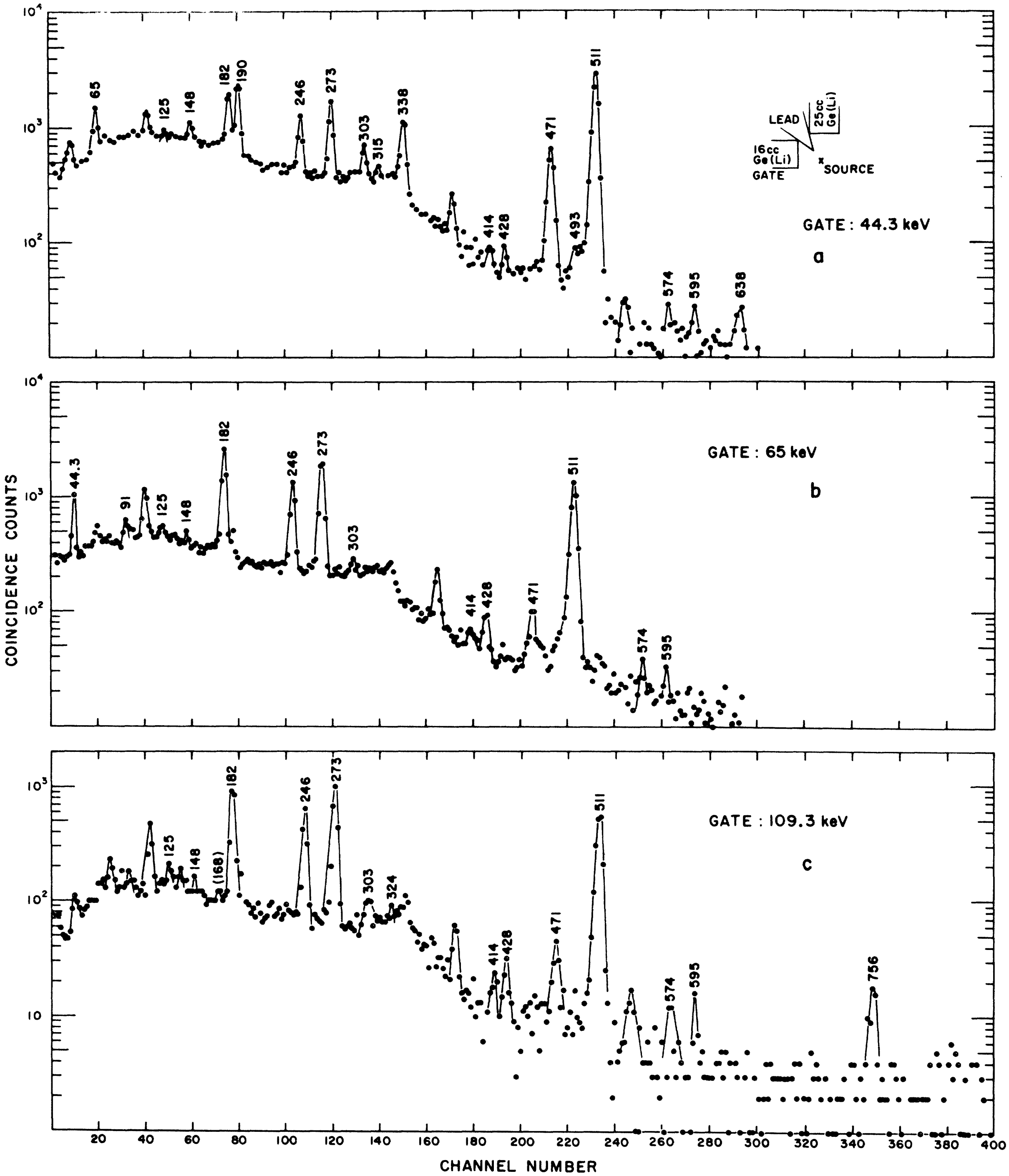

FIG. 3. Ge(Li) spectra of Ge^{66} γ rays in coincidence with the (a) 44.3-keV photopeak, (b) 65-keV photopeak, and (c) 109.3-keV photopeak.

can well account for all the γ rays and all their intensity balances (listed in Table I), except that of 471 keV. The apparent inconsistency is in connection with the intensity balance for the 234.5-keV level, which is fed by the 471-keV γ ray and depopulated mostly via the 190-keV line. From Table I it is obvious that the 471-keV γ ray has a relative intensity of 43±4, as compared to 25±3 for the 190-keV line. The relative intensities for the 125- and 234.5-keV γ rays are very small. This point was recently explained by McClure

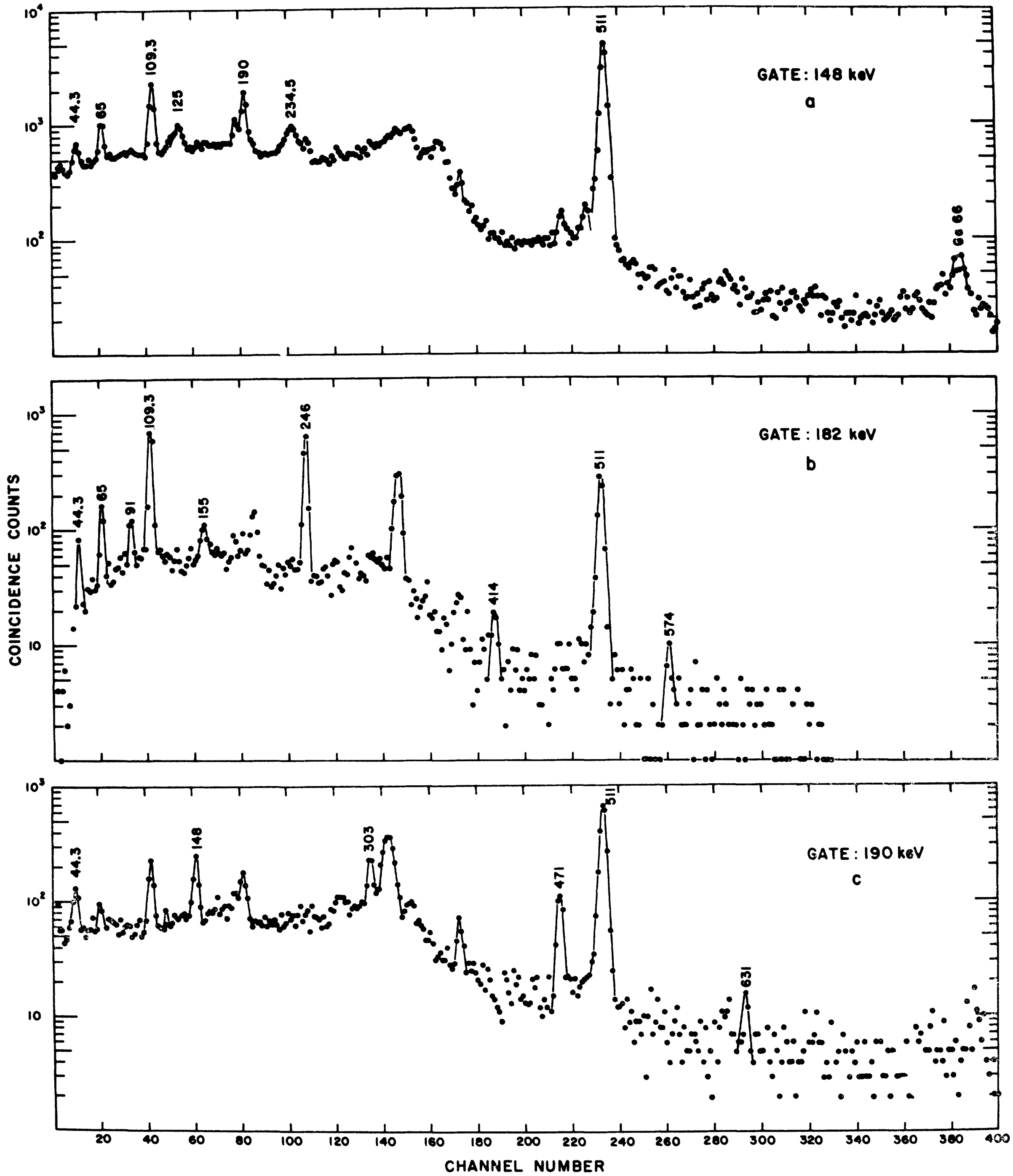

FIG. 4. Ge(Li) spectra of Ge^{66} γ rays in coincidence with the (a) 148-keV photopeak, (b) 182-keV photopeak, and (c) 190-keV photopeak.

and Bolotin[6] by assuming a level at 515 keV. The coincidence of 471 keV with the 44.3-keV γ ray gives a level at 515 keV. Assuming this to be correct, one can calculate the intensity for the 471-keV γ ray which deexcites the 705-keV level. By comparing the 190–471-keV cascade intensity with the 44–471-keV cascade, it was possible to obtain a value of 58 and 42% for the intensity of the 471-keV γ rays which deexcite the levels

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[6] D. A. McClure and H. H. Bolotin, Bull. Am. Phys. Soc. 13, 1426 (1968); H. H. Bolotin, *ibid.* 8, 524 (1963).

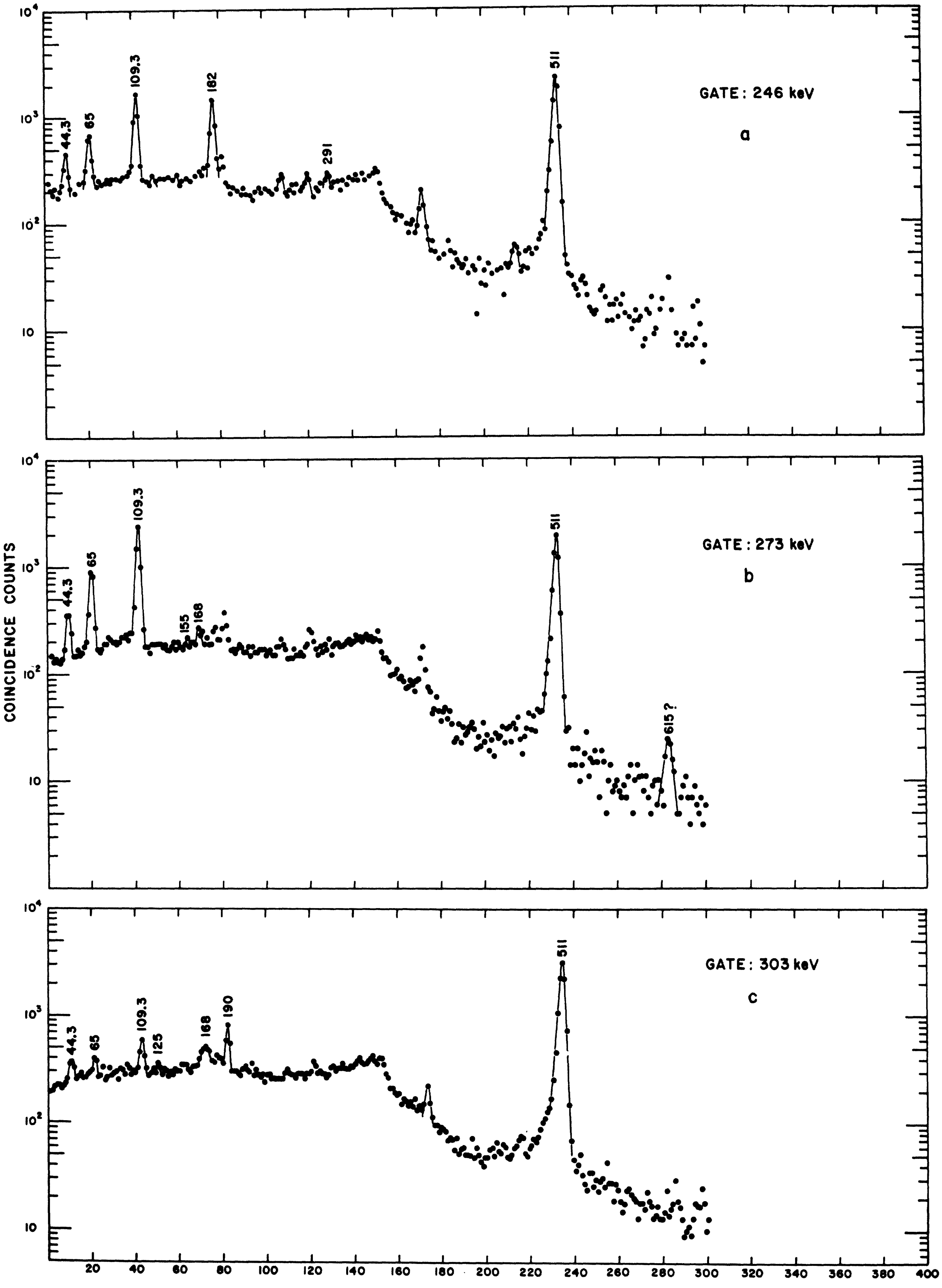

FIG. 5. Ge(Li) spectra of Ge^{66} γ rays in coincidence with the (a) 246-keV photopeak, (b) 273-keV photopeak, and (c) 303-keV photopeak.

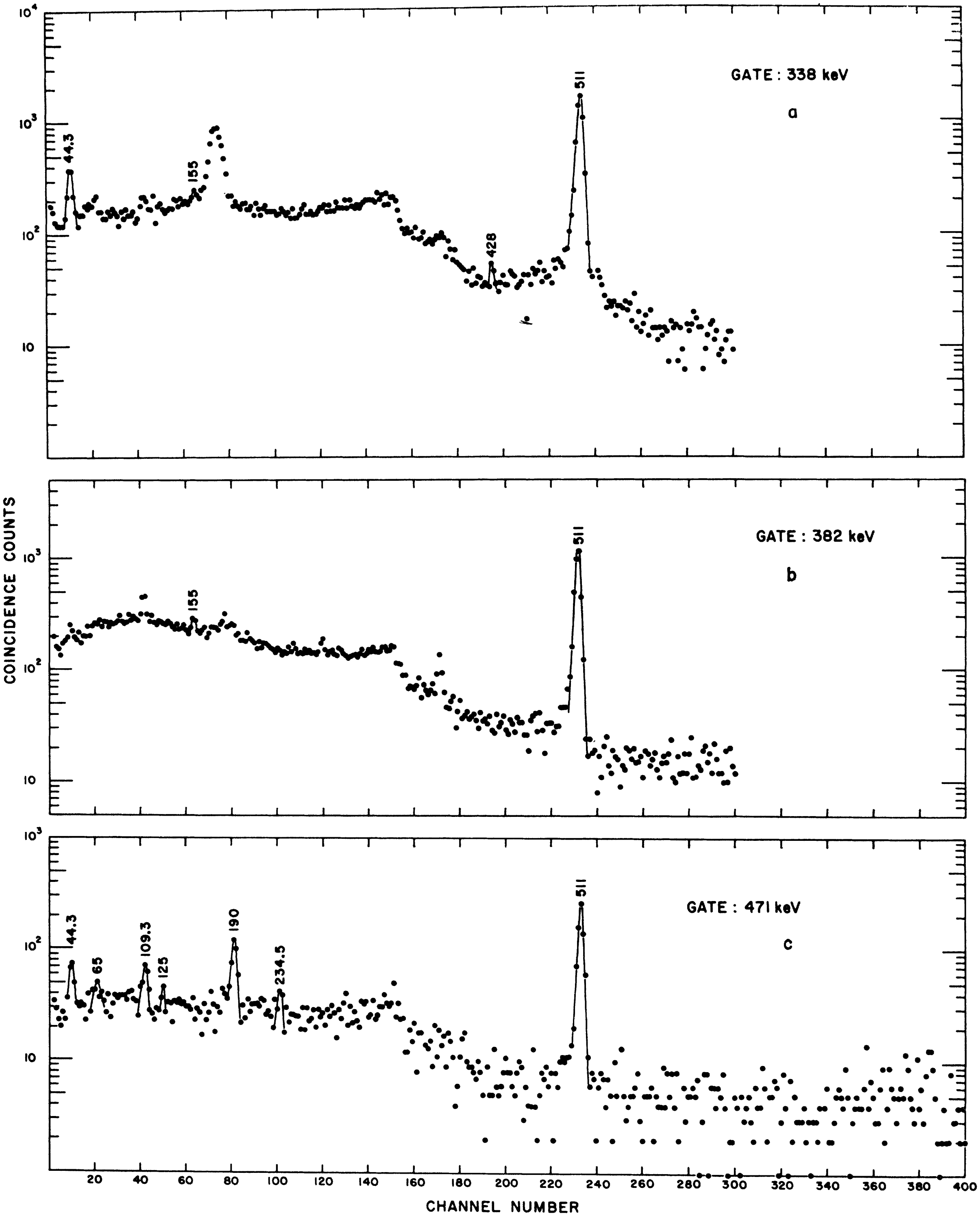

FIG. 6. The three spectra (a)-(c) are in coincidence with the 338-, 382-, and 471-keV photopeaks, respectively.

at 705 and 515 keV, respectively. While both the intensity balance and positron intensity measurements indeed support the existence of a 515-keV level, it should be noted that there are some problems in connection with each of these arguments. The measurement of the positron energy and intensity have large errors and may be fortuitous and, furthermore, no other γ rays depopulating the 515-keV level have been observed.

TABLE II. Ge^{66}: Results of γ-γ coincidences.

Energy of gate (keV)	44.3	65	109.3	126	182	190	246	273	303/338	382	414	428	471	537	595.5	756
44.3	No	2	No	0.2	5	6	4	6.5	316=1 303=2 (338=7±3)	No	Yes	3	10±2	No	Yes	Yes
65	Yes (8)	No (91=2)	No 148 (Yes)	Yes	31	No	20	40	Yes 303 No 338	No	Yes	Yes	5	No	Yes	Yes
109.3	No	No	No	2	24	No	18	40	Yes 303	No	2±1	6±2	2.5	No	3	6
182	Yes (6)	10	40	91=(5) 155=(5)	No	No	70	No	No	No	3±1	No	No	No	No	No
190	Yes (16)	No	(148=20)	No	No	No	No	No	303=(35)	No	No	No	50	No	No	No
246	Yes (18)	13	40	No	54	No	No	No	No	No	No	No	No	No	No	No
273	Yes (10)	15	41	(168=0.5)	No	No	No	No	No	No	No	No	No	No	No	No

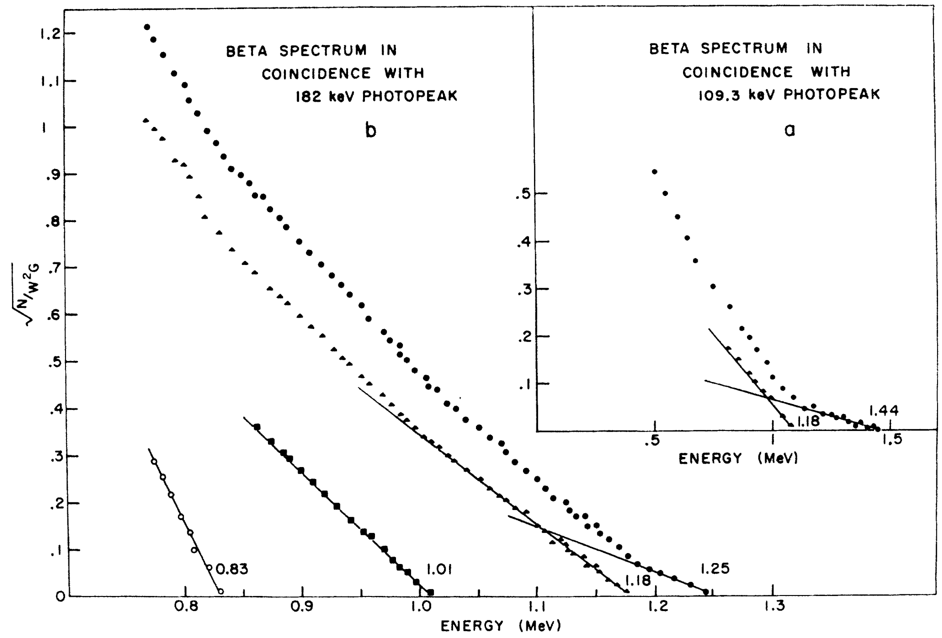

FIG. 7. Fermi-Kurie plot of β spectra in coincidence with (a) the 109.3-keV line and (b) the 182-keV photopeak.

Even the γ-ray spectra taken with a biased amplifier did not show any indication of 515-keV ground-state transition due to the presence of very high-intensity 511-keV line. Having taken notice of the weaknesses in the evidence for a level at 515 keV, we nevertheless propose this as a level in our decay scheme.

C. Triple-Coincidence Results

The previously reported[2] two γ rays of 380 keV in cascade giving rise to levels at 380 and 760 keV in Ga^{66} were not seen in the γ-γ coincidence measurements. In order to confirm that the 382 keV is a single γ ray, the following experiment was performed. A 25-cm³ Ge(Li) detector was used in conjunction with two 3-in.×3-in. NaI(Tl) detectors. The Ge(Li) and one of the NaI(Tl) detectors were placed at 90° to each other. The second NaI(Tl) detector was placed on the top of these two detectors so that all the detectors faced an angle of 90° to each other. Sufficient lead was placed in between the counters to avoid Compton scattering. The ORTEC fast triple-coincidence ($2\tau=40$ nsec) unit was used for the triple coincidence. The triple coincidence was tested by selecting 511- and 1270-keV gates in the two NaI(Tl) crystals and using a strong Na^{22} source. No 511-keV counts were observed even after 10 h of accumulation. The chance-coincidence rate was checked by selecting 511 and 511 keV in both gates. The NaI(Tl) detectors were used to select the 109.3- and 273-keV photopeaks as the gates and the Ge(Li) detector recorded the spectrum in coincidence with the 109.3- and 273-keV photopeaks. Use of several Ge^{66} sources was made. These sources were capsuled in a 1-in.×1-in. Plexiglass to stop the high-energy positrons. No peak at 382 keV was observed, which confirmed our γ-γ coincidence result: namely, that there is only one 382-keV level.

D. β-γ Measurements

The direct β spectrum on Ge^{66} taken with a cooled Si(Li) detector (model TMC W-80-3AA) yielded no information due to the immediate growth of Ga^{66}, which has a positron group above 4 MeV. Hence, coincidence measurements were made to eliminate the contamination from Ga^{66}. For β-γ measurements thin sources (1 mg/cm²) of Ga^{66} were prepared. The resolving time of the coincidence circuit was kept as $2\tau=50$ nsec. The γ-ray gate was selected with a 25-cm³ Ge(Li) detector and the β spectrum was recorded in a 1-in.-thick×2-in.-diam anthracene crystal. After the chemical separation the source was counted only for 30 min and then rejected. The spectrometer was calibrated with the known conversion lines of Bi^{207}, Cs^{137}, and the endpoint energy of Sr^{90}. Figures 7(a) and 7(b) show the Fermi-Kurie plot of the β spectrum in coincidence with the 109.3- and the 182-keV photopeak. The spectrum in coincidence with the 109.3-keV photopeak shows β endpoint energy of 1.44 MeV. By analyzing the Fermi-Kurie plot the following groups with endpoint energies of 1.25, 1.18, 1.01, and 0.830 MeV were obtained. The β spectrum in coincidence with 182 keV photopeak

TABLE III. Results of β-γ coincidences.

γ-ray energy gate (keV)	Coincident β groups (in MeV)
109.3	1.44, 1.25, 1.18, 1.01, 0.830
182	1.25, 1.18, 1.01, 0.830
382	1.18, 1.01, 0.830
705	0.830 (complex)

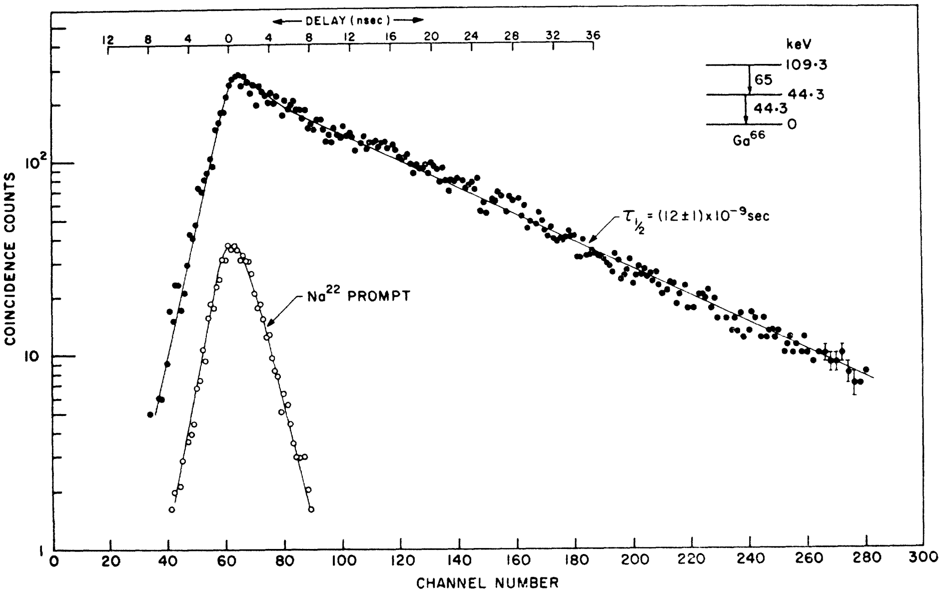

FIG. 8. The prompt and the delayed time spectra using two NaI(Tl) detectors. The time spectrum of coincidences between the 44.3- and the 65-keV transitions is shown by closed circles. The prompt curve taken with Na^{22} at the same energy settings is shown by open circles.

shows an endpoint energy of 1.25 MeV. The intensity of the 1.18 MeV β group in this figure (which is in coincidence with the 182-keV γ ray by virtue of the weak 91-keV γ ray) is as strong as the 1.25-MeV group for the following reason. The 182-keV γ ray sits on the top of strong Compton background of the 246-, 273-, 338-, and 382-keV lines. The Compton edge of the 338-keV line falls exactly at the 182-keV gate. Because of this Compton background, which is in coincidence with the 1.18-MeV β group, the 1.18-MeV group is as strong as 1.25-MeV group. Only the lower part of the 182-keV line was chosen as a gate so as to avoid the contribution from the 190-keV line. Table III summarizes all the β-γ coincidence results.

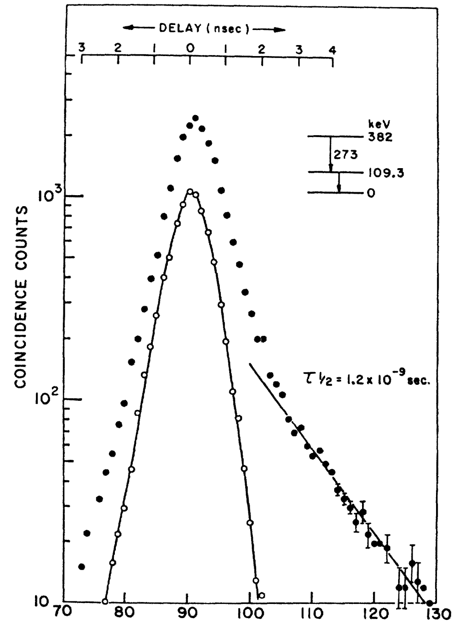

FIG. 9. The prompt and the delayed time spectra using plastic detectors. The time spectrum of coincidences between the 109.3- and the 273-keV transitions is shown by closed circles. The prompt curve taken with Na^{22} at the same energy settings is shown by open circles.

E. Lifetime of the 44.3- and 109.3-keV Levels

A possible approach to the question of multipolarities is the investigation of the lifetime of the levels. In the present experiment, we have measured the half-life of the 44.3- and 109.3-keV levels.

For the measurement of lifetime of the 44.3-keV level, two 1-in.×1-in. NaI(Tl) crystals coupled to Amperex XP 1020 photomultipliers were used. Care was taken to ensure that all the positrons from the source were stopped outside the scintillators. Fast signals were derived from two ORTEC fast discriminators and fed into an ORTEC time–to–pulse-height converter. The energy selection channels were set in order to accept the 44.3 keV in one side. The other single-channel analyzer was set either for the 65-keV or the 190-keV photopeak. The coincidence ($2\tau=40$ nsec) between these two channels selected the coincidence between the 44.3-keV and 65- or 190-keV γ rays. The coincidence output was used to gate a multichannel analyzer, whose input was the spectrum from the time–to–pulse-height converter. The resultant time spectrum recorded in the analyzer is shown in Fig. 8. The half-life measured for the 44.3-keV state is $(12\pm1)\times10^{-9}$ sec. The earlier measurement[6] reported the half-life of the 44.3-keV state as $(21\pm2)\times10^{-9}$ sec. Since the details of their experiment are not yet published, no possible explanation of the discrepancy is given. Using NaI(Tl) detectors the lifetime of the 109.3-keV state was found to be very close to the slope of the prompt resolution curve of Na^{22} at the same

TABLE IV. Transition probabilities in Ga^{66}.

Transition (keV)	$\tau_{1/2}$ s.p. (sec)[a] $M1$	$E2$	$\tau_{1/2}$ expt. (sec) $M1$	$E2$	$M1$ retardation τ expt./τ s.p.	$E2$ enhancement τ s.p./τ expt.
44.3	1×10^{-10}	1.5×10^{-5}	12×10^{-9}	12×10^{-9}	120	1.3×10^{3}
109.3	1×10^{-11}	1.7×10^{-6}	1.9×10^{-9} [b]	1.7×10^{-9} [b]	190	1.0×10^{3}

[a] Single-particle Weisskopt estimates, corrected for electron conversion.

[b] Calculated from M. E. Rose, *Internal Conversion Coefficients* (North-Holland Publishing Co., Amsterdam, 1958).

channels. To improve the prompt resolution two Naton plastic scintillators of 1 in.×1 in. and $\frac{3}{4}$ in.×$\frac{3}{4}$ in. were used with Amperex XP 1020 phototubes. The energy selection channels were set as follows. For pulses from the smaller scintillator, the channel was set to accept the entire Compton spectrum of the 109.3-keV γ ray which is above the noise. For the larger scintillator, the selected pulses were those whose heights were above the Compton edge of 109.3 keV and below the Compton edge of the 382-keV γ rays. This selected mainly the Compton edge of the 246- and the 273-keV γ rays. The time spectrum is shown in Fig. 9. The half-life measured for the 109.3-keV state is $(1.2\pm0.2)\times10^{-9}$ sec. The full width at half-maximum for the Na^{22} prompt curve at these energy channels is about 1 nsec. The measured lifetimes of the 44.3- and 109.3-keV levels are compared with the Weisskopf estimates in Table IV. Since only one transition comes out of the 44.3-keV level, the measured lifetime is to be directly compared to the calculated single-particle lifetime. One finds that if the 44.3-keV transition is assumed to be a pure $E2$, then it would be an $E2$ which is enhanced by 1.3×10^{3}. Such a large enhancement, although perhaps not impossible, is at least unlikely. On the other hand, if the 44.3-keV transition is a pure $M1$ transition, then it has the much more reasonable retardation value of 120. Such retarded $M1$ transitions are known to occur in this mass region. Similar comparisons can also be made for the 109.3-keV transition. Because the 109.3-keV state is depopulated by both the 109.3- and 65-keV transitions, a definite assumption has to be made with respect to the character of the 65-keV transition. The partial half-lives for the 109.3-keV γ ray in Table IV were calculated from the measured half-lives of the 109.3-keV state, assuming the 65-keV transition to be mostly $M1$. Had this transition been assumed to be $E2$, the numbers would have been changed by about a factor of 2.5. This difference would not have altered our conclusion that the 109.3-keV transition must be predominantly $M1$.

IV. DISCUSSION

The results of the present experiments are summarized in the level scheme shown in Fig. 10. The

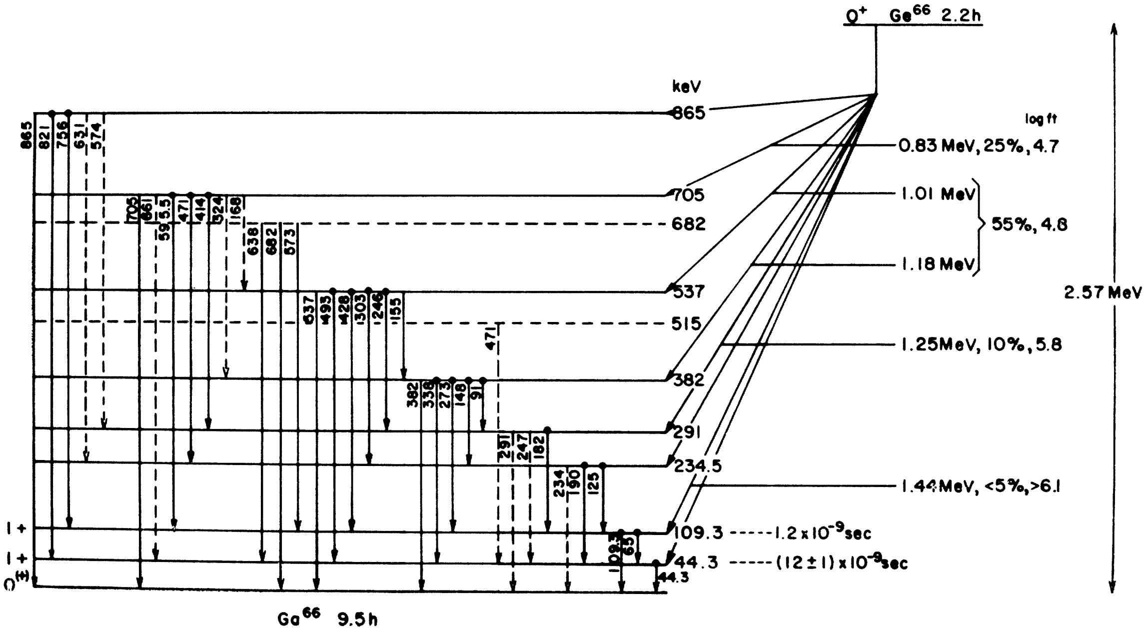

FIG. 10. Decay scheme of 2.2-h Ge^{66}.

error in the reported values of the energies of the levels is ±1 keV or better. The solid lines indicate that these γ-rays or the levels have been confirmed by the energy, intensity, and various coincidence results. The dashed lines indicate that these γ rays or levels are weakly populated and could not be confirmed by all of the above three methods.

The total decay energy of Ge^{66} amounts to 2.57 MeV. The spin of Ge^{66} is assumed to be 0^+, while that of the daughter Ga^{66} has been measured to be 0, and the parity is almost certainly even. A weak positron branch ($<5\%$ $\log ft=6.1$) of the 1.44-MeV level leads to the 109.3-keV level, and there may be a weak positron branch feeding the ground state as well as the 44.3-keV level (not confirmed by these experiments). The small intensity (assumed as $<1\%$) of this ground-to-ground branch ($\log ft \geq 6.8$) might indicate a first forbidden transition. However, it is known that the direct β transition between the Ga^{66} ground state and that of Zn^{66}, which is also of the type of $0^+ \rightarrow 0^+$, has a $\log ft=7.8$. Therefore, it seems that the β transitions between the three respective ground states, which are forbidden both on Gamow-Teller and on Fermi selection rules, proceed only by virtue of small isobaric spin admixtures in the $T=1$ (Ge^{66}), $T=2$ (Ga^{66}), and $T=3$ (Zn^{66}) states.

The log*ft* values shown in Fig. 10 have been calculated from the intensity of the measured positron branches, and using theoretical capture to positron ratios. The limit on the intensity of the ground state to ground-state decay was obtained to be smaller than 1% by comparing the measured positron intensity with the positron intensity expected from the decay scheme. However, it should be noted that this number is very likely to have large errors due to the presence of very high energetic positrons from the decay of Ga^{66}. The spin values of the 44.3- and 109.3-keV levels are probably 1, as suggested from the retarded $M1$ transitions, the shell-model considerations strongly suggest even parity. Recently, Bolotin[6] assigned the levels of Ga^{66} from the decay of Ge^{66}. In discussing their proposed decay scheme McClure and Bolotin presented a level scheme identical to ours, except for the 865-keV level. In their level scheme the spins for the 291-, 382-, 537-, and 706-keV levels were suggested to be 1^+. The level at 865 keV reported by us was not shown in the work of McClure and Bolotin. This is easily explained on the basis of source purity. We have used 99.9%-enriched Zn^{64} for our studies, whereas McClure and Bolotin used natural Zn^{64}, which produced a large amount of Ge^{69} as a source impurity. Because of the presence of Ge^{69}, the low-intensity, high-energy γ rays of Ge^{66} could not be observed by these authors.

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