place at approximately right angles to the direction of the bremsstrahlung.

A total of 54 stars resulting from the photodisintegration of O^{16} into four alpha particles were analyzed. In this reaction the photon energy (and hence the O^{16} excitation energy) is given by $E_{tot}+14.5$ Mev, where E_{tot} now represents the total kinetic energy of the four alpha particles and 14.5 Mev is the threshold for this reaction. Figure 5 shows the distribution of the above 54 events according to E_{tot} as well as the distribution of the 4×54 alpha particles according to the alpha particle energy. The results shown in Fig. 5 appear to corroborate previous work[3,4] on this reaction.

[3] E. W. Titterton, Phys. Rev. 94, 206 (1954).
[4] I. I. Wilkins and F. K. Goward, Proc. Phys. Soc. (London) 64, 1056 (1951).

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Radioactive Decays of Rh^{106} and Ag^{106}

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Transitions in Pd^{106} occurring in the decays of Rh^{106} and Ag^{106} have been examined with a three-crystal pair spectrometer using gray-wedge pulse-height analysis, single and coincidence scintillation spectrometer techniques and an intermediate-image beta-ray spectrometer. In addition to lines previously known, gamma rays of 1.77, 1.96, 2.10, and 2.66 Mev and a possible gamma ray of 1.14 Mev are found in Rh^{106} decay. Gamma rays of energies 0.22, 0.409, 0.51, 0.62, 0.72, 0.805, 1.045, 1.131, 1.205, 1.23, 1.39, 1.55, 1.77, 1.85, 2.1, and 2.63 Mev are observed in Ag^{106} decay. Most of the data can be satisfied by postulating in addition to the five previously known states in Pd^{106} three new weakly excited levels at 1.85, 2.27, and 2.66 Mev. A lower limit of $\sim10^{-8}$ sec is estimated for the partial half-life of the 0-0 transition between the second excited and ground states of Pd^{106}.

INTRODUCTION

In a previous study[1] of the decay of Rh^{106}, undertaken because of interest in the angular correlation of the gamma rays from this isotope, excited states in Pd^{106} at 0.513, 1.137, 1.55, and 2.41 Mev were proposed from the results of beta- and gamma-ray measurements. The level scheme has been confirmed by the gamma-ray and angular correlation experiments of Kraushaar and Goldhaber,[2] of Arfken, Klema, and McGowan,[3] and of Klema and McGowan.[4]

Pd^{106} is also reached in the electron capture decay of Ag^{106} and Hayward has reported[5] transition energies of 0.220, 0.409, 0.511, 0.620, 0.717, 0.815, 1.04, 1.24, and 1.55 Mev from measurements on the internal conversion electron spectrum. A state in Pd^{106} at 1.77 Mev together with the levels previously established in the Rh^{106} work is sufficient to make all of the reported Ag^{106} gamma rays fit in energetically with the exception of the 0.717- and 0.815-Mev lines. Although the energy of the 0.409-Mev Ag^{106} gamma ray agrees with the separation between the 1.55- and 1.137-Mev levels, the corresponding gamma ray has not been observed in Rh^{106} decay.

Kahn and Lyon later investigated[6] Rh^{106}, finding new gamma rays of 1.14, 1.76, and 2.28 Mev, and they proposed an additional level in Pd^{106} at 2.28 Mev. For the purpose of determining further details of the Pd^{106} level structure and to search for a possible 0-0 transition from the second excited state to the ground state we have reinvestigated Rh^{106} and have examined the internal conversion and gamma-ray spectra of Ag^{106}.

EXPERIMENTAL

The three-crystal pair spectrometer[7] was found to be of considerable value in the present work and is thought to be especially useful between 1 and 3 Mev for detecting weak high-energy gamma rays in the presence of intense low-energy components and for obtaining somewhat better gamma-ray resolution than in singles spectra. For a NaI crystal detector having a singles resolution of 9% at 0.661 Mev, the three-crystal *gamma-ray* resolution as a function of energy can be computed readily on the assumption that the line width is proportional to $\sqrt{E}$, where E is the pulse energy. At low energies, bremsstrahlung broadening effects can be neglected. The calculated resolution function rises from 0% at the $2mc^2$ threshold energy to a maximum of about 3.7% at $4mc^2$ gamma-ray energy and then drops off very slowly at higher energies. However, above 3 Mev, bremsstrahlung loss by the pairs from the center crystal will cause a low-energy tail on the two-annihi-

* Under contract with U. S. Atomic Energy Commission.
[1] D. E. Alburger, Phys. Rev. 88, 339 (1952).
[2] J. J. Kraushaar and M. Goldhaber, Phys. Rev. 89, 1081 (1953).
[3] Arfken, Klema, and McGowan, Phys. Rev. 86, 413 (1952).
[4] E. D. Klema and F. K. McGowan, Phys. Rev. 91, 616 (1953).
[5] R. H. Hayward, Phys. Rev. 85, 760 (1952); see Hollander, Perlmann, and Seaborg, Revs. Modern Phys. 25, 469 (1953).
[6] B. Kahn and W. S. Lyon, Phys. Rev. 92, 902 (1953).
[7] R. Hofstadter and J. A. McIntyre, Phys. Rev. 79, 389 (1950); S. A. E. Johansson, Nature 166, 794 (1950); J. K. Bair and F. C. Maienschein, Rev. Sci. Instr. 22, 343 (1951).

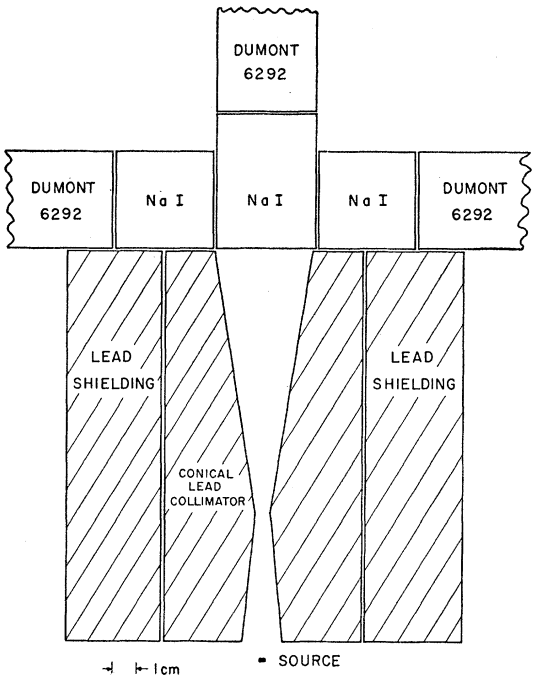

FIG. 1. Geometry of the three-crystal pair spectrometer.

lation-quanta escape peak and this effect results in poorer resolution with increasing energy and a large continuum of low-energy pulses. The spectra of gamma rays between 1 and 3 Mev are characterized by low background between lines. The fact that the pair cross section at these energies is relatively small has not proved to be particularly disadvantageous in our work,

Our experimental arrangement, as shown in Fig. 1, includes a NaI display crystal 4 cm in diameter and 5.5 cm long mounted on a DuMont 6292 photomultiplier tube, two side crystals of 4 cm in diameter and 4 cm long, and a double conical lead collimator 16 cm long which shields the side crystals from direct radiation without reducing appreciably the flux on the center crystal.

For recording the two-quantum escape peak in the center crystal we have used two models of a coincidence gray-wedge analyzer. The first of these has already been described[8] while the second[9] is an improved version, designed by R. L. Chase, containing two built-in single-channel pulse-height analyzers and a triple-coincidence circuit having a resolving time of 0.1 μsec. Center crystal counting rates of up to 50 000 per sec can be accommodated without appreciable distortion or loss of small pulses in the three-crystal spectrum. The side crystal channels are set so as to include only the full energy loss peak of annihilation radiation. After fast coincidences have been formed, the side channels impose further slow coincidence conditions by the use of standard Rossi circuit techniques. In our earlier work, a Polaroid Land camera was used for preliminary qualitative experiments while pictures from which more careful analyses of gamma-ray energies and intensities were made, such as all of those included in this paper, were taken with a 35-mm camera. Processing of the film was carried out by the Photographic Department of the laboratory. Since the completion of the experiments described here, techniques have been developed which to a large extent eliminate the need for 35-mm photographs. For energy measurement it has proved to be just as accurate to read peak positions on polaroid photographs by means of a 20× microscope equipped with a movable stage. A vernier scale permits the positions of peaks relative to the base line to be determined with an accuracy of 0.1 mm. For intensity measurements an iso-density plot can be made giving a curve which agrees well with the true spectrum as observed with a channel analyzer.

The results of tests on the three-crystal pair spectrometer given in Figs. 2 and 3 illustrate some of the advantages of this device over single-crystal counting in the 1–3 Mev region. Figure 2 is the spectrum of the 1.17- and 1.33-Mev gamma rays of Co^{60} obtained in a 16-hour exposure by using a 2-mC source. The lower-energy line has an energy of $1172-1022=150$ kev and its half-width is 17 percent, or 25 kev. This corresponds to an effective gamma-ray resolution of 25/1172 or 2.1% in agreement with that expected from the resolution function mentioned above. The high-energy tail observable on the 1.33-Mev peak is due to the addition of a slight amount of energy to the pair pulse when

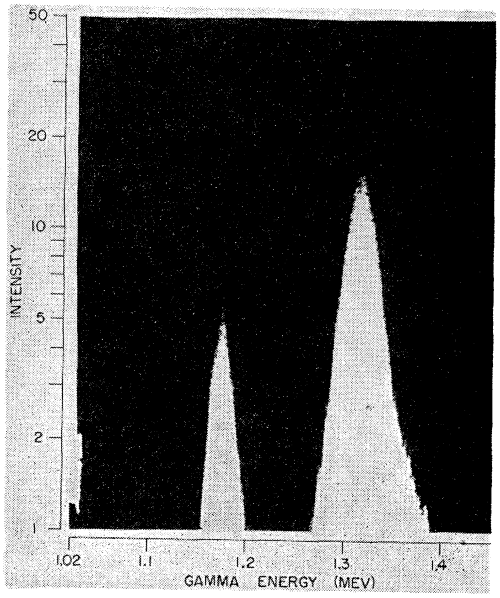

FIG. 2. Three-crystal pair spectrum of Co^{60} gamma rays.

[8] R. L. Chase, Brookhaven National Laboratory Report BNL 263 (*T*-42) (unpublished); see also Bernstein, Chase, and Schardt, Rev. Sci. Instr. 24, 437 (1953), and A. W. Schardt, Brookhaven National Laboratory Report BNL 237 (*T*-37) (unpublished).

[9] Copies of the circuit diagram may be obtained by writing to the authors.

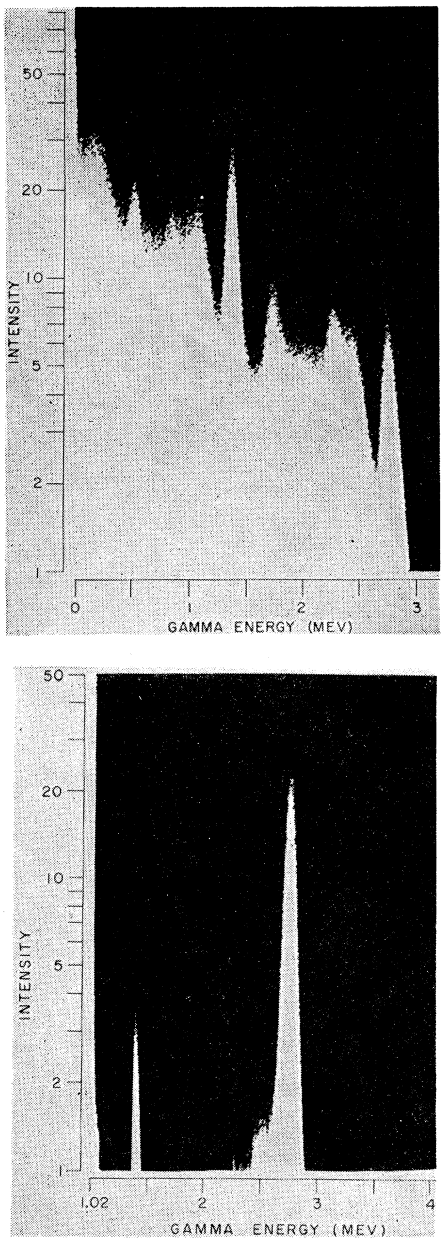

FIG. 3. Upper photograph—single-crystal spectrum of Na^{24} gamma rays. Lower photograph—three-crystal pair spectrum taken at the same gain setting.

annihilation quanta undergo small-angle scattering before leaving the center crystal. Small-angle scattering degrades the energy by only a slight amount and still allows the annihilation gamma-ray pulses to fall within the side channels. This effect is not expected to be noticeable at higher energies although it gives further justification for keeping the side channels as narrow as is consistent with the width of the annihilation radiation full energy loss peak.

In Fig. 3 where the single-crystal and three-crystal spectra of Na^{24} were photographed at the same gain, the advantage of the much greater simplicity of the three-crystal spectrum is evident. In the single-crystal picture the two-quantum escape line of the 1.37-Mev gamma ray is not clearly visible. The three-crystal spectrum was obtained in a 1-hour exposure (approximately 12 000 total pair counts) using a 2-mC source. It should be pointed out that the peaks in the lower part of Fig. 3 are larger, in spite of the triple coincidence condition, than the corresponding two-escape peaks in the singles photograph because of a longer exposure. In the case of the 2.75-Mev pair line, the half-width is approximately 5.6%, or 97 kev, which corresponds to an effective gamma-ray resolution of 3.5%, in close agreement with the value expected. This peak displays a small bremsstrahlung-loss tail on the low-energy side.

From Figs. 2 and 3, the relative efficiencies at 1.17, 1.35, and 2.75 Mev can be calculated from the areas under the peaks if the intensities of the 1.33-Mev Co^{60} peak and the 1.37-Mev Na^{24} peak are normalized. Within the errors of about 10 percent the three points fit the relative pair cross sections in iodine from the curve published by Mann *et al.*[10]

As a test of the three-crystal pair spectrometer on a complex spectrum including components of somewhat higher energy, the gamma rays in the decay of Ga^{66} were investigated with the results shown in Fig. 4. Sources were made by 22-Mev deuteron bombardment of zinc in the Brookhaven cyclotron and Fig. 4 is from a 2-hour exposure at 200 pair counts per min. The ten resolved gamma rays have energies of 1.89, 2.14, 2.38, 2.73, 3.23, 3.35, 3.76, 4.14, 4.27, and 4.78 Mev which

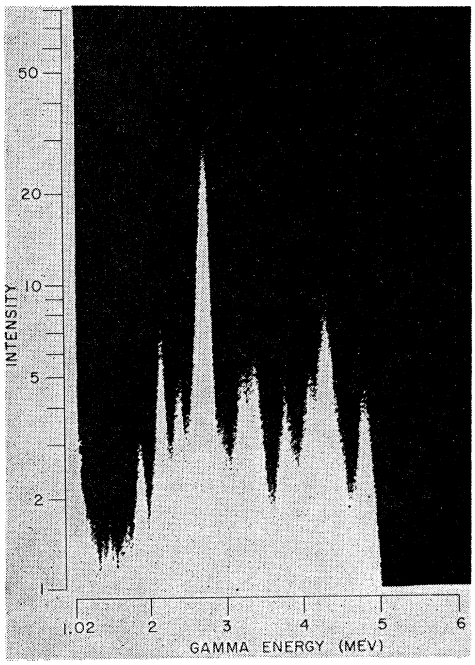

FIG. 4. Three-crystal pair spectrum of Ga^{66}.

[10] Mann, Meyerhof, and West, Phys. Rev. **92**, 1481 (1953).

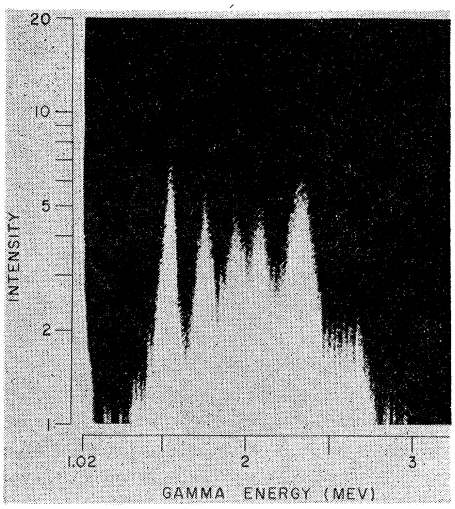

FIG. 5. Three-crystal pair spectrum of Rh^{106} gamma rays.

agree within the errors of ~2% with those reported[10] by Mann *et al.* Relative intensities are essentially the same as in their spectrum. Presumably because of greater source strength and better statistics the peaks in Fig. 4 are somewhat more clearly defined than in the corresponding curve of Mann *et al.* Photographs taken over a period of two half-lives showed that all of the lines decay with a 9-hour half-life. There is no clear evidence in the three-crystal spectrum for the 1.4-Mev gamma ray found by Mann *et al.* in a Compton spectrometer arrangement.

An iron-free intermediate-image beta-ray spectrometer[11] was used for internal and external conversion measurements on Ag^{106} sources. At the time the data were taken, a temporary baffle system was in use which gave a resolution of 1.0% and a transmission of 3.0% of 4π. Line width due to source size is 0.3% per mm diameter.

TABLE I. Rh^{106} and Ag^{106} gamma-ray intensities normalized to a value of 100 for the 0.513-Mev gamma ray. A dashed line indicates that the gamma ray was not observed and a question mark means that a reliable intensity value cannot be given.

E_γ(Mev)	Intensity in Rh^{106} decay	Intensity in Ag^{106} decay
0.22	—	?
0.409	—	?
0.513	100	100
0.624	53	20
0.72	—	20
0.805	—	?
0.87	3	—
1.045	8	31
1.131	≤0.8	10
1.205	—	~10
1.225	—	
1.39	—	10
1.55	2.5	33
1.77	1.0	6
1.85	—	5
1.96	0.6	—
2.1	0.5	1
2.41	1.0	—
2.66	0.2	0.3

[11] D. E. Alburger, Rev. Sci. Instr. **25**, 1025 (1954). A more detailed report will be published later.

Rh^{106} Gamma-Ray Spectra

The Rh^{106} gamma rays above 1 Mev were examined using the three-crystal pair spectrometer techniques described in the preceding section. Figure 5 shows the result of a 60-hour exposure at 2.5 counts/min using a 20-mC source obtained from Oak Ridge. To exclude the possibility of peaks resulting from unusual triple coincidence effects involving the intense 0.513- and 0.624-Mev gamma rays, data were taken with 1.27- and 2-cm lead filters between the source and collimator.

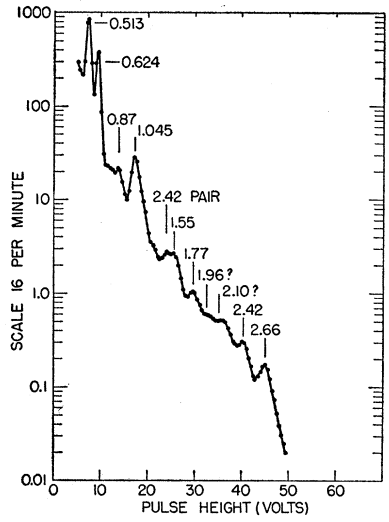

FIG. 6. Single-crystal spectrum of Rh^{106} using a 2 in.×2 in. crystal and recording data with a 20-channel analyzer.

The spectra observed were closely similar to Fig. 5. Runs were also made with a weaker source three years old which displayed essentially the same features but with poorer statistics. Assuming that no impurities are present with approximately the same half-life, all of the lines can be assigned to Rh^{106}. Their energies are 1.55, 1.77, 1.96, 2.10, 2.37, and 2.66 Mev with probable errors of 2–3%. Their intensities are included in Table I and are normalized to the 1.55-Mev transition intensity in the previously proposed scheme.[1] Intensities were calculated by determining the peak height, correcting for width, and dividing by the pair cross section.[10] The 1.55- and 2.37-Mev lines evidently correspond to the 1.55- and 2.41-Mev gamma rays found previously[1] and the 1.77-Mev gamma ray agrees with one of the lines found by Kahn and Lyon.

An attempt was made to observe some of the new Rh^{106} gamma rays in the single-crystal spectrum of a 2 in.×2 in. NaI crystal detector. Figure 6 shows the spectrum recorded with an Atomic Instruments Com-

pany 20-channel pulse-height analyzer when the source was 20.5 inches from the crystal. The statistics are better than 2% for all points. All of the Rh^{106} gamma rays found previously, with the exception of the weak 1.96- and 2.10-Mev lines, whose expected positions are indicated, are clearly identifiable in the figure. From curve construction a line at 1.14 Mev having an intensity 25% as strong as the 1.04-Mev gamma ray, as reported[6] by Kahn and Lyon, would have been visible in Fig. 6. On the other hand, from a detailed study of the 1.04-Mev photopeak its shape does not seem to be consistent with that of a single gamma ray. A gamma ray of about 1.1 Mev having a relative intensity ~10% of the 1.04-Mev gamma is probably present. A further study of the 1.04-Mev line was made with a Compton spectrometer. Although the line had a slightly abnormal appearance it was not possible to prove definitely the presence of a 1.14-Mev component. The singles spectrum was also examined for gamma rays of 0.22 and 0.4 Mev. The latter, if present, has a maximum intensity of 2% of the 0.513-Mev gamma ray. A small peak found at about 0.22 Mev is probably associated with room backscattering.

Coincidence experiments using two large crystals and a gray-wedge analyzer were carried out on the Rh^{106} gamma rays. Channeling on the 0.513-Mev gamma ray, lines at 0.62 and 1.04 Mev were found in the coincidence spectrum together with weak structure up to about 2.0 Mev. When the channel was moved to 1.04 Mev the coincidence spectrum contained the 0.51- and 0.87-Mev gamma rays. By further narrowing down the channel and centering it on the 1.137 sum peak (0.51- and 0.62-Mev gamma rays) a search was made in the coincidence spectrum for a possible gamma ray of 0.41 Mev. No line of this energy could be found.

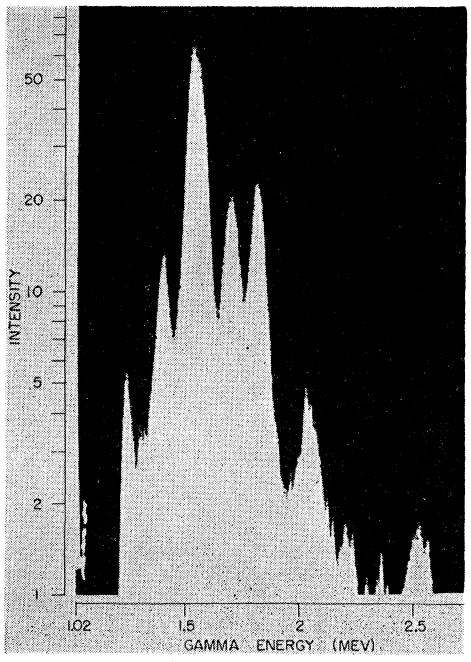

FIG. 7. Three-crystal pair spectrum of Ag^{106} gamma rays.

TABLE II. Internal conversion lines in the decays of Ag^{105} and Ag^{106}.

Electron energy (Mev)	Assignment	Isotope	Relative intensity
0.0406	*K*-0.065	Ag^{105}	20
0.0624	*L*-0.065	Ag^{105}	156
0.0925	*K*-0.117	Ag^{105}	7.5
0.114	*L*-0.117	Ag^{105}	4.5
0.134	*K*-0.158	Ag^{105}	42
0.161	*K*-0.185	Ag^{105}	68
0.184	*L*-0.185	Ag^{105}	16
0.203	*K*-0.227	Ag^{106}	180
0.225	*L*-0.227	Ag^{106}	57
0.263	*K*-0.287	Ag^{105}	475
0.285	*L*-0.287	Ag^{105}	87
0.303	*K*-0.328	Ag^{105}	39
0.327	*K*-0.351	Ag^{105}	52
0.343	*L*-0.351?	Ag^{105}	86
0.371	*K*-0.395	Ag^{105}	36
0.384	*K*-0.408	Ag^{106}	135
0.408	?	—	—
0.422	*K*-0.446	Ag^{105}	93
0.445	*L*-0.446	Ag^{105}	13
0.489	*K*-0.513	Ag^{106}	567
0.509	*L*-0.513	Ag^{106}	74
0.595	*K*-0.624	Ag^{106}	95
0.624	*L*-0.624	Ag^{106}	—
0.694	*K*-0.72	Ag^{106}	78
0.721	*L*-0.72	Ag^{106}	—
0.780	*K*-0.805	Ag^{106}	45
0.803	*L*-0.805	Ag^{106}	—
1.025	*K*-1.045	Ag^{106}	37
1.107	*K*-1.131	Ag^{106}	13
1.181	*K*-1.205	Ag^{106}	12
1.201	*K*-1.225	Ag^{106}	7
1.364	*K*-1.388	Ag^{106}	1.8
1.506	*K*-1.53	Ag^{106}	10

Ag^{106} Gamma-Ray and Internal Conversion Spectra

Ag^{106} was made by bombarding palladium metal with 22-Mev deuterons in the Brookhaven cyclotron. The three-crystal pair spectrum given in Fig. 7 shows that gamma rays of 1.21, 1.39, 1.54, 1.72, 1.85, 2.10, and 2.63 Mev are present together with some evidence of additional structure between 2 and 2.5 Mev. Photographs taken over a period of 3 weeks showed that all of the lines decayed with the 8.5-day half-life of this isotope.

This activity was also examined with a single-crystal scintillation spectrometer and an intermediate-image beta spectrometer using silver chemically separated from Pd targets. From a study of the scintillation spectrum we find gamma rays of 0.22, 0.51, 0.62, 0.72, 1.045, 1.2, (1.4), and 1.55 Mev decaying with the half-life characteristic of Ag^{106} and lines of 0.063, 0.27, and 0.33 Mev which decay at a much slower rate, presumably being associated with Ag^{105}. A line of about 0.42 Mev decays at an intermediate rate and may include the 0.41-Mev Ag^{106} gamma ray and the 0.44-Mev Ag^{105} line reported by Hayward. Relative intensities of the Ag^{106} gamma rays from the single-crystal spectrometer and three-crystal pair spectrometer measurements are included in Table I.

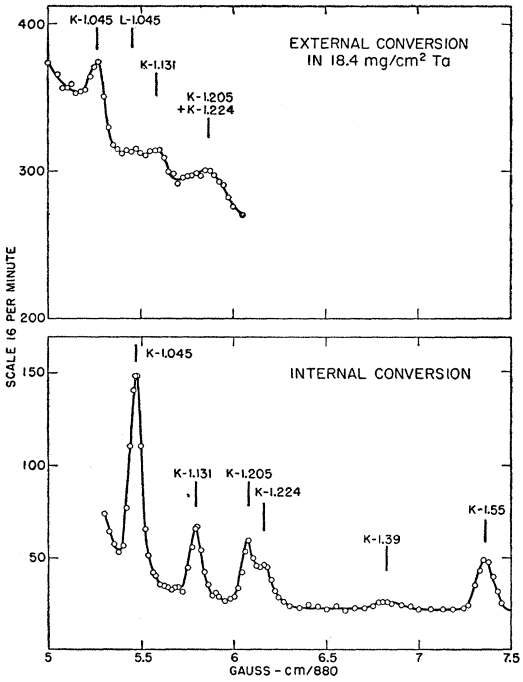

FIG. 8. Internal and external conversion spectra of Ag^{106} in the region of 1 Mev.

The intermediate-image beta spectrometer was used at 1% resolution to examine the internal conversion electrons from separated Ag activity. A very complex spectrum was observed containing the conversion electron lines of Ag^{105} and Ag^{106} and the 1-Mev beta-ray spectrum of Ag^{111}. Table II gives a list of the conversion line energies, intensities corrected for decay and probable isotope assignments made on the basis of a study of the decay of the spectrum over a period of one month. All of the Ag^{106} gamma-ray energies reported by Hayward are confirmed, but in addition conversion lines corresponding to transitions of 1.131 and 1.205 Mev are present which decay with the Ag^{106} half-life. This region of the spectrum, which is just above the Ag^{111} beta end point, is shown in the lower part of Fig. 8.

The energy of the 1.131-Mev conversion line suggested that it might be associated with a possible 0-0 transition of 1.137 Mev from the second excited state to the ground state of Pd^{106}. Probable errors on both of these energies are ~5 kev. With scintillation spectrometers it was not possible to prove definitely either with Rh^{106} or Ag^{106} sources whether or not a gamma ray of this energy is present. A measurement was therefore carried out on the photoelectrons from a Ta converter using a silver source in the intermediate-image spectrometer. The line half-width resulting from the 18.4-mg/cm² thickness and the 3-mm diameter of the converter was ~1.6%. Ta rather than Pb or U was selected as a converter in order to separate the L-1.045 line from an expected K-1.131 line. As shown in the upper part of Fig. 8 there is definite evidence of a K photoline corresponding to a 1.131-Mev gamma ray. Its intensity is approximately $\frac{1}{3}$ of the 1.045-Mev gamma-ray intensity which is about the same as the ratio of the internal conversion lines.

DISCUSSION

The foregoing results are summarized in an energy level diagram for Pd^{106} given in Fig. 9. This should be considered only as tentative since it has not been possible to establish the positions of all of the transitions by experiment. The scheme contains eleven Rh^{106} gamma rays and fifteen Ag^{106} gamma rays where those in the center of the figure are common to both activities. While all of the Rh^{106} transitions are included, the only Ag^{106} gamma ray for which no position has been found is that of 1.205 Mev. In order to fit the gamma-ray energies, new levels of 1.85, 2.27, and 2.66 Mev have been added to the previous decay scheme.[12] The last of these is the most certain since it is likely that the 2.66-Mev gamma ray is a ground-state transition. The 1.85-Mev level is involved in the 0.409-, 0.72-, 0.805-, 1.39-, and 1.85-Mev transitions of Ag^{106} and the 2.27-Mev level furnishes an explanation of the 1.131- and 0.409-Mev transitions.

Alternate positions of several of the gamma rays are possible. For example the 1.77-Mev transition could take place between the 2.27- and 0.513-Mev levels and the 0.22-Mev gamma ray between the 2.66- and 2.42-Mev levels. Except for the 1.23-Mev gamma ray this

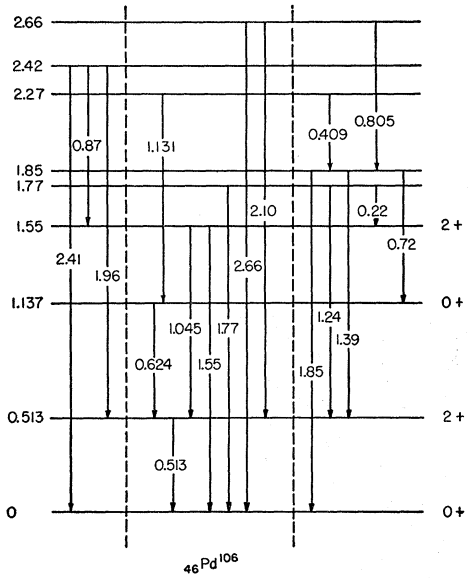

FIG. 9. Proposed levels and transitions in Pd^{106}. In the center between dashed lines are transitions common to both Rh^{106} and Ag^{106}. To the left are transitions observed only in Rh^{106} decay and to the right those observed only in Ag^{106} decay.

[12] M. Goldhaber and R. D. Hill, Revs. Modern Phys. 24, 179 (1952).

would obviate the necessity of postulating a level at 1.77 Mev.

Spin and parity assignments to the new levels, if indeed the states exist in the suggested positions, cannot be made from the present data. The same highly excited level at 2.66 Mev is reached in both decay processes and the level structure of Pd^{106} is somewhat more complex than previously thought. It is not expected that the presence of the additional weak high-energy gamma rays in the decay of Rh^{106} or low-energy components which could be present but have not yet been detected would have an appreciable effect on the gamma-gamma angular correlation. It has already been shown[2-4] that the relatively strong gamma rays of 0.513, 0.624, and 1.045 Mev and the spin and parity assignments given in Fig. 9 can account for the measured angular correlations.

The possible 0-0 cross-over transition from the 1.137-Mev level is of considerable theoretical interest. Unfortunately a 1.131-$\pm$0.005-Mev gamma ray is present in the Ag^{106} spectrum and its conversion lines hinder a study of the 0-0 transition. An upper limit for the 0-0 cross-over intensity relative to the 0.624-Mev transition may be obtained as described in the following. The 1.045-Mev transition is known to take place between two states of 2+ and it must therefore be $M1$ or $M1+E2$. At 1 Mev and $Z=46$ the K-conversion coefficients for $M1$ and $E2$ differ by less than 20 percent while the smallest possible α_K is that for $E1$ radiation which is about half as great as for $E2$ radiation. Figure 8 suggests that the intensity ratio of the 1.045- and 1.131-Mev photo lines is about the same as the ratio of the corresponding internal conversion lines. If all of the 1.131-Mev internal conversion line intensity were associated with the 1.131-Mev gamma ray transition, then the conversion coefficient of the 1.131-Mev gamma ray would be about the same as that of the 1.045-Mev gamma ray, i.e., $M1$ or $E2$. Variations in the conversion coefficient and in the photoelectric cross section with energy are small over this interval and have been neglected. Since the conversion coefficient of the 1.131-Mev gamma ray cannot be less than that of an $E1$ transition at least half of the 1.131-Mev conversion line must be associated with the 1.131-Mev gamma ray. Thus one can conclude that less than half of the K-1.131 line is associated with the 1.137-Mev 0-0 transition. By using the ratio of 7 for K-0.624/K-1.131 from Table II, it follows that K-0.624/K-1.137_{0-0} must be >14. Since the conversion coefficient[1] of the 0.624-Mev $E2$ gamma ray is 2.9×10^{-3}, the relative cross-over branch could be at most 2×10^{-4} neglecting L conversion and possible nuclear pair emission. This number may be used to derive a lower limit for the partial half-life of the 0-0 transition if one can first estimate the lifetime of the 1.137-Mev state. The lifetime of the 0.513-Mev first excited state, which also decays by $E2$ radiation, has been calculated by Stelson and McGowan[13] as 1.02×10^{-11} sec based on the results of Coulomb excitation. According to the considerations[14] of Scharff-Goldhaber and Weneser, the 0.624-Mev transition probably takes place between 2-phonon and 1-phonon states and the 0.513-Mev transition between 1-phonon and 0-phonon states. Their estimate is that along with the E^5 energy-dependence factor a speed-up factor of about 2 should be included in calculating the transition probability of the 0.624-Mev gamma ray. There is as yet no empirical evidence to support this choice of speed-up factor. This leads to an estimated lifetime of $\sim2\times10^{-12}$ sec for the 1.137-Mev state. The upper limit of the 0-0 branching intensity given above thus results in a lower limit of $\sim10^{-8}$ sec for the partial half-life of the 0-0 transition.

Calculations of the transition probability for electric monopole transitions have been carried out by Drell and Rose[15] and by Church and Weneser.[16] For a 1.1-Mev transition at $Z=46$, the uninhibited lifetime is $\sim3\times10^{-10}$ sec. Hence it would appear that the probability for the 0-0 transition in Pd^{106} is inhibited by a factor of >30 which corresponds to an inhibition factor $\rho<\frac{1}{5}$ in the matrix element, if one uses the notation of Church and Weneser.

A further study of the 0-0 transition in Pd^{106} might be rewarding if it becomes possible to resolve its conversion lines from those of the 1.131-Mev gamma ray. From Fig. 8 there is no suggestion of structure in the 1.131-Mev K-conversion line at 1% resolution and it is clear that at least 0.1–0.2% resolution would be necessary to detect a second component if present. An actual value of the $E0$ inhibition factor rather than just an upper limit would be of considerably greater value.

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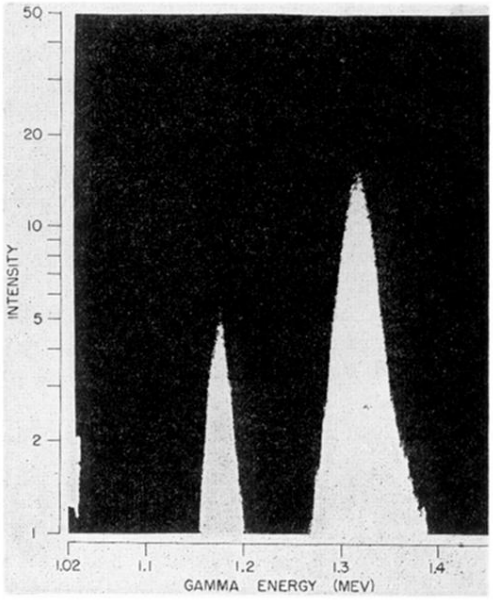

FIG. 2. Three-crystal pair spectrum of Co^{60} gamma rays.

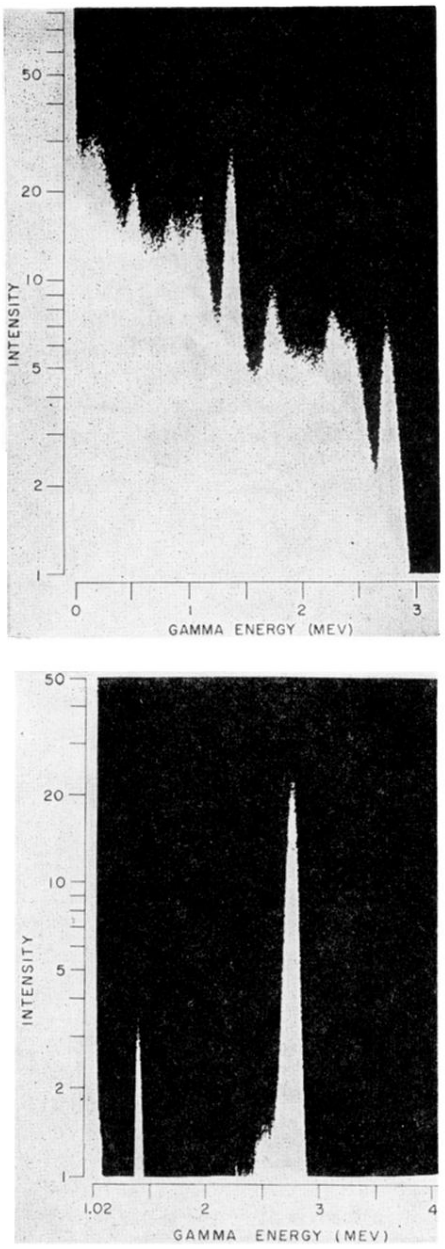

FIG. 3. Upper photograph—single-crystal spectrum of Na^{24} gamma rays. Lower photograph—three-crystal pair spectrum taken at the same gain setting.

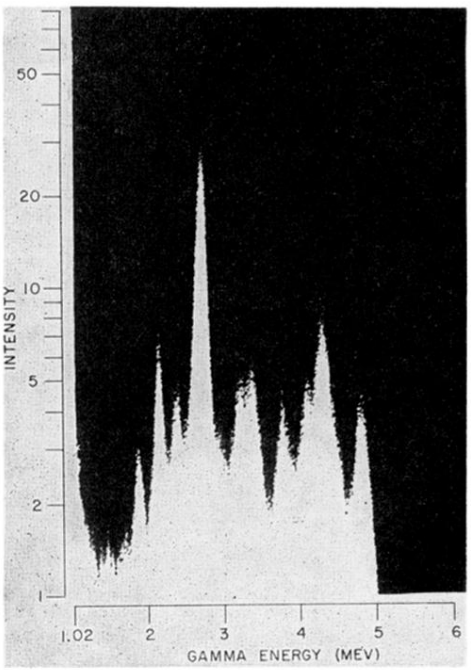

FIG. 4. Three-crystal pair spectrum of Ga^{66}.

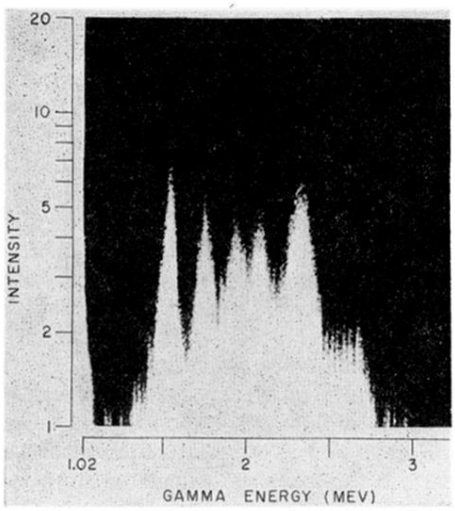

FIG. 5. Three-crystal pair spectrum of Rh^{106} gamma rays.

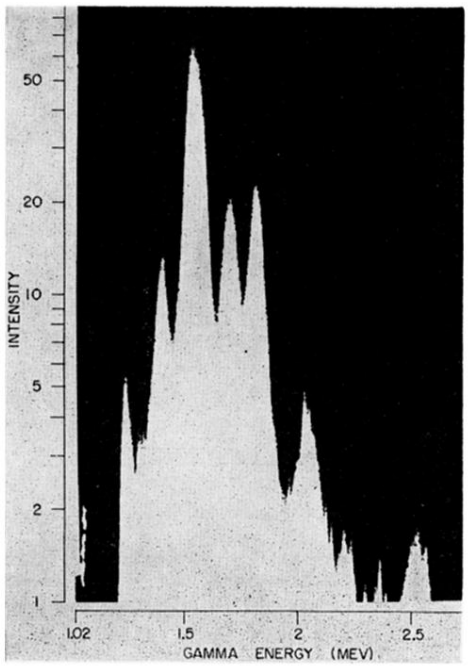

FIG. 7. Three-crystal pair spectrum of Ag^{106} gamma rays.