mated here do not completely eliminate the possibility of a rather unusual statistical fluctuation. However, they do raise the question that perhaps some direct-capture or channel-resonance phenomena of the kind proposed by Lane and Lynn[24] may be occurring.

[24] A. M. Lane and J. E. Lynn, Nucl. Phys. **17**, 563 (1960); **17**, 586 (1960).

ACKNOWLEDGMENTS

The authors wish to express their gratitude to D. Shores and R. Vogt for their assistance in setting up our experiment and gathering our data. We are also grateful to Dr. K. W. Marlow, Dr. A. Stolovy, and Dr. T. Godlove for useful discussions and advice.

Transitions in ^{107}Pd Following 22-min ^{107}Rh Decay*

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We have studied the decay of ^{107}Rh by γ-ray spectroscopy using Ge(Li) detectors and Ge(Li)-NaI(Tl) $\gamma\gamma$ coincidence techniques. A decay scheme has been constructed incorporating all but six of the 39 transitions reported. This decay scheme involves excited states in ^{107}Pd at 115.6, 302.8, 312.2, 348.2, 381.8, 392.5, 471.2, 567.7, 670.0, 1102, and 1148 keV. A half-life of 850 ± 100 nsec was found for the 115.6-keV level, and $\gamma\gamma$ delayed-coincidence spectroscopy was employed to determine the features of the decay scheme related to this level. β branching ratios and logft values have been derived from the relative γ-ray intensities and the β/γ ratio. We find that the β decay of ^{107}Rh tends to avoid populating ^{107}Pd levels that have strong single-particle character [that is, levels populated strongly in (d, p) and (d, t) reactions].

I. INTRODUCTION

SEVERAL years ago the decay of 22-min ^{107}Rh was studied[1] by scintillation spectroscopy. A number of β and γ transitions were fitted into a decay scheme, but the poor resolution of the measurements precluded any formulation of a decay scheme that was more than tentative.

Strong impetus for exploiting the better resolution now obtainable with semiconductor detectors stems from recent studies of ^{107}Pd levels by (d, p) and (d, t) spectroscopy[2–4]—particularly the high-resolution (d, p) work[3]—which established a number of new levels and produced information concerning some probable spins. These results were interpreted in terms of the distributions of single-particle strengths for the neutrons in the N=51–82 shell.

An investigation of the decay of ^{107}Rh is of interest in terms of a comparison of the types of information which can be obtained by β, γ spectroscopy versus reaction spectroscopy. The earlier decay-scheme work[1] indicated that the spin of ^{107}Rh is high, though not as great as $\frac{9}{2}$ units. In the single-particle model[5] the only high-spin configuration for the 45th proton in the ground state is $1g_{9/2}$. In the region of 45 protons or neutrons, $\frac{7}{2}+$ and $\frac{5}{2}+$ ground states are encountered frequently. The reason for this is not clear, but in any event the structures of these ground states are probably not simple (see, for example, Ref. 6). Thus one might expect the decay of ^{107}Rh to select states in ^{107}Pd which contrast with those strongly populated in ^{106}Pd(d, p) and ^{108}Pd(d, t) reactions, since the latter states presumably are, respectively, single-particle and single-hole states.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A. Source Preparation

The ^{107}Rh was produced by reactor-neutron fission of ^{235}U. Ruthenium (including 4.2-min ^{107}Ru, which decays to ^{107}Rh) was isolated chemically. After an appropriate waiting period, ^{107}Rh was separated from the ruthenium.

In greater detail, the procedure was as follows: Uranyl nitrate solution (containing about 1 mg of ^{235}U) was irradiated for 5 min at a flux of 2×10^{12} n cm^{-2} sec^{-1}. Ruthenium carrier was added to the irradiated solution, and the solution was boiled to drive off the gaseous fission products. The ruthenium was distilled (as RuO_4)

* Work supported in part by the Michigan Memorial—Phoenix Project.
[1] W. R. Pierson, H. C. Griffin, and C. D. Coryell, Phys. Rev. **127**, 1708 (1962).
[2] B. Čujec, Phys. Rev. **131**, 735 (1963).
[3] B. L. Cohen, J. B. Moorhead, and R. A. Moyer, Phys. Rev. **161**, 1257 (1967).
[4] B. L. Cohen, R. A. Moyer, J. B. Moorhead, L. H. Goldman, and R. C. Diehl, Phys. Rev. **176**, 1401 (1969).
[5] M. G. Mayer and J. H. D. Jensen, *Elementary Theory of Nuclear Shell Structure* (John Wiley & Sons, Inc., New York, 1955).
[6] A. Goswami and O. Nalcioglu, Phys. Letters **26B**, 353 (1968).

from a mixture of perchloric and phosphoric acids (10:1 by volume) and sodium bismuthate into cold hydrochloric acid.[7] Twelve minutes later the distillate was fumed to dryness with perchloric acid to remove the ruthenium from its carrier-free rhodium daughters.

Purification of the rhodium involved coprecipitation of carrier-free rhodium with iron hydroxide, precipitation of $K_3Rh(NO_2)_6$ (with rhodium carrier, and with tartrate present to keep the iron in solution), and reduction of rhodium to the metal with magnesium, in that order.[8] These procedures are based, for the most part, on published radiochemical procedures for rhodium and ruthenium.[9] We have not demonstrated that all of these steps are necessary, although modifications to standard procedures were motivated by the presence of small amounts of impurities (γ-ray emitters) in samples prepared by simpler methods. (Even with the full procedure described above, an occasional sample showed low-level γ-ray components indicative of impurities.) Other rhodium species expected (and observed under appropriate conditions) were 53-min ^{103m}Rh (from 40-day ^{103}Ru) and 35.4-h ^{105}Rh (from 4.4-h ^{105}Ru).

Sources prepared by the foregoing procedure contained about a microcurie of ^{107}Rh in approximately 5 mg of finely-divided rhodium metal distributed over a circular area of diameter 1.75 cm on a disk of glass-fiber filter paper.

B. γ-Ray Measurements

Information obtained in the series of experiments described below is summarized in Table I. As implied by the column headings, there were four kinds of measurements: (a) the γ-ray spectrum ("singles" measurements), (b) $\gamma\gamma$ prompt coincidences, (c) $\gamma\gamma$ delayed coincidences, and (d) $\gamma\gamma$ coincidences corresponding to selected energy sums (i.e., sum-coincidence spectra).

Energies and intensities. Most of the energies and intensities were measured by means of Ge(Li) detectors, of which there were three: one 0.5-cm$\times$4-cm^2 planar device with resolution at 300 keV of 2.3 keV full width at half-maximum, one 10-cm^3 coaxial device with resolution 4 keV, and one 24-cm^3 "modified coaxial" (trapezoidal rather than cylindrical cross section) device with resolution 2.6 keV. Low-energy measurements (down to 10 keV) were made with a 3-mm$\times$1-cm^2 Si(Li) detector with system resolution 0.6 keV. Measurements were also made in certain cases with NaI(Tl) detectors.

The energy scale for each of the γ-ray spectra was obtained by the use of standards for which accurate energies have been reported. The singles Ge(Li) spectra were given the most careful attention in this respect, and the detailed procedures are described below in the section dealing with these spectra. Once the energies of the main components in the ^{107}Rh spectrum had been obtained, these served as secondary standards in the coincidence spectra. Some of the low-energy, low-intensity γ rays are seen best in Ge(Li) coincidence spectra, however, and in these cases we have considered the coincidence data in estimating the energy.

The intensities were obtained by correction of full-energy peak areas for differences in peak efficiencies. For the Ge(Li) detectors, from which most of the intensities were obtained, efficiency curves were constructed with the aid of sources having two or more γ rays of known relative intensities, namely, ^{22}Na, ^{75}Se, ^{108m}Ag, ^{152}Eu, and ^{207}Bi. For each standard source, a log–log graph of relative efficiency versus energy was drawn. These several curves were then combined into one which best fitted all of them. Areas for peaks in both standard spectra and ^{107}Rh spectra were determined by summing the counts in a block of channels centered at the peak position, and subtracting the average of similar blocks of channels on either side of the peak. A more complicated procedure for estimating the height of the continuum under a peak was sometimes necessary when the close spacing of known γ rays interfered with the simple procedure, or in regions (near a Compton edge, for example) where the continuum could not be approximated as a linear function of channel number. The efficiency curve constructed for each detector over the region 80–1200 keV can best be described as a smooth curve through the efficiency values obtained using ^{75}Se (relative intensities taken from Ref. 10) and ^{108m}Ag (Ref. 11). The curves are in good agreement with the compiled[12] relative-intensity values for the ^{152}Eu γ rays of 344.4, 411.2, 779, and 965 keV (others not examined), but they are not in good agreement with the relative intensities for ^{133}Ba as given by Gurfinkel and Notea[13] and recommended by them as an intensity standard.

The intensities are given in Table I under the column heading appropriate to the type of measurement to

[7] The boiling step prevents contamination of the distillate by the nonvolatile daughters of gaseous fission products (e.g., ^{138}Cs produced by the decay of ^{138}Xe).

[8] We find that precipitation of $Fe(OH)_3$ using sodium hydroxide carries rhodium more nearly quantitatively than precipitation using ammonium hydroxide. We find also that dissolution of $K_3Rh(NO_2)_6$ in HCl is strongly accelerated by the presence of a small amount of H_2O_2.

[9] See E. I. Wyatt and R. R. Rickard (National Academy of Sciences—National Research Council monograph No. NAS-NS-3029, 1961), and J. C. Armstrong, Jr., and G. R. Choppin (National Academy of Sciences—National Research Council monograph No. NAS-NS-3008, 1965), both available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va.; also *Radiochemical Studies: The Fission Products*, edited by C. D. Coryell and N. Sugarman (McGraw-Hill Book Co., New York, 1951), Div. IV, Vol. 9, Papers 258, 260, and 262.

[10] P. V. Rao, D. K. McDaniels, and B. Craseman, Nucl. Phys. **81**, 296 (1966).

[11] W. R. Kane and M. A. Mariscotti, Nucl. Instr. Methods **56**, 189 (1967).

[12] C. M. Lederer, J. M. Hollander, and I. Perlman, *Table of Isotopes* (John Wiley & Sons, Inc., New York, 1967), 6th ed.

[13] Y. Gurfinkel and A. Notea, Nucl. Instr. Methods **57**, 173 (1967).

TABLE I. γ rays in the decay of ^{107}Rh.

1	2	3	4	5	6	7	8	9
No.	E_γ (keV)	Singles intensity (%)[a]	Intensity in prompt coinc. with gross γ[b,c]	Intensity in delayed coinc. with 115.6-keVγ[b,d]	Intensity in $\approx$1100-keV$\gamma\gamma$ sum coinc.[b,e]	Intensity in $\approx$670-keV$\gamma\gamma$ sum coinc.[b,f]	Intensity in $\approx$560-keV$\gamma\gamma$ sum coinc.[b,g]	Assignment[h] to ^{107}Rh
1	Pd K_α, K_β x rays	1.16	···	···	···	···	···	definite (internal conversion)
2	80.06±0.3	0.05±0.01	0.04	···	···	0.004	···	definite (392.5→312.2)
3	96.6±0.5	(0.009)	0.008	···	···	···	≈0.005	probable (567.7→471.2)
4	102.4±0.5	≈0.02(0.02)	···	···	···	0.01	···	probable (670.0→567.7)
5	115.65±0.2	0.52	0.02	···	···	0.01	0.02	definite (115.6→0)
6	175.3±0.5	0.07±0.01(0.06)	0.05	···	···	···	0.04	probable (567.7→392.5)
7	198.7±0.5	0.04±0.01	···	···	···	0.05	···	probable (670.0→471.2)
8	219.4±0.5	0.10±0.02	0.08±0.02	···	···	···	≡0.10	definite (567.7→348.2)
9	232.37±0.3	0.21±0.03	0.2	0.17	...	···	0.2	definite (348.2→115.6)
10	266.06±0.2	0.28±0.02	0.3	0.26	···	···	0.3	definite (381.8→115.6)
11	277.58±0.2	1.70	1.7	···	···	1.8	0.2	definite (670.0→392.5)
12	288.28±0.2	0.73	0.8	0.26	···	0.4	0.4	definite (670.0→381.8)
13	302.77±0.2	65.9	2.2	i	···	1.9	1.0	definite (302.8→0)
14	312.21±0.2	4.79	0.7	···	0.02	0.4	0.2	definite (312.2→0)
15	321.84±0.2	2.26	≡2.26	0.27	···	2.2	0.5	definite (670.0→348.2)
16	348.21±0.2	2.27	2.3	···	···	2.4	0.6	definite (348.2→0)
17	357.84±0.2	0.41	0.4	···	···	0.4	···	definite (670.0→312.2)
18	367.31±0.2	1.91	1.7	···	···	≡1.91	0.4	definite (670.0→302.8)
19	381.86±0.2	0.65	0.7	···	present?	0.6	0.1	definite (381.8→0)
20	392.47±0.2	8.75	2.3	i	0.03	2.6	0.7	definite (392.5→0)
21	431.7±0.5	0.026±0.006	···	···	···	···	···	possible (1102→670.0)
22	451.88±0.2	0.51	···	≡0.51	···	···	≈0.05	definite (567.7→115.6)
23	471.21±0.3	0.12	···	···	···	···	0.09	definite (471.2→0)
24	511.7±0.5	0.03±0.02	···	···	···	···	···	possible
25	521.2±0.6	0.02±0.01	···	···	···	···	···	possible

TABLE I (*Continued*)

1 No.	2 E_γ (keV)	3 Singles intensity (%)[a]	4 Intensity in prompt coinc. with gross γ[b,c]	5 Intensity in delayed coinc. with 115.6-keVγ[b,d]	6 Intensity in $\approx$1100-keV$\gamma\gamma$ sum coinc.[b,e]	7 Intensity in $\approx$670-keV$\gamma\gamma$ sum coinc.[b,f]	8 Intensity in $\approx$560-keV$\gamma\gamma$ sum coinc.[b,g]	9 Assignment[h] to ^{107}Rh
26	554.42±0.3	0.078	···	···	···	···	···	definite (670.0→115.6)
27	567.70±0.2	1.15	0.05±0.02	···	···	···	···	definite (567.7→0)
28	643.9±0.8	0.032±0.004	···	···	···	···	···	probable
29	670.05±0.2	2.22	···	···	···	···	···	definite (670.0→0)
30	696.7±0.8	0.012±0.003	···	···	···	···	···	possible
31	709.5±0.5	0.075	0.07±0.03	···	0.04	···	···	definite (1102→392.5)
32	720.4±0.6	0.013±0.002	···	···	present?	···	···	possible (1102→381.8)
33	753.8±0.8	0.013±0.003	···	···	···	···	···	possible (1102→348.2)
34	789.9±0.4	0.089	0.09±0.03	···	≡0.09	···	···	definite (1102→312.2)
35	836.5±1	0.015±0.003	···	···	···	···	···	possible (1148→312.2)
36	845.4±1	0.025±0.003	···	···	···	···	···	possible (1148→302.8)
37	863.4±1	0.037±0.003	···	···	···	···	···	possible
38	1101.9±1	0.011±0.003	···	···	···	···	···	probable (1102→0)
39	1120.0±1	0.024±0.004	···	···	···	···	···	possible
40	1148.5±1	0.039±0.004	···	···	···	···	···	probable (1148→0)
···	(1100 sum±40)[j]	0.2 to 0.34[k]						definite

[a] Absolute intensities are based on the assumption that the sum of the intensities of γ rays Nos. 13, 14, and 15 is 73% of the ^{107}Rh disintegrations as implied by Ref. 1. The intensities are given for γ rays alone, *without internal conversion*. The three values in parentheses are based on coincidence measurements. Corrections for coincidence summing have been applied as necessary (see text). Errors quoted are only the estimated errors of obtaining peak areas and do not include uncertainties in the efficiency curves, errors in conversion to absolute intensities, or other factors; see text for fuller discussion. When peak-area errors are not specified, they are smaller than 7%.

[b] Intensities are calculated relative to the indicated γ rays, which have been selected in terms of the ease with which the coincident intensities can be correlated with absolute intensities. Corrections have not been made for differences in efficiencies for presumed partners in the NaI(Tl) detectors. Such corrections have been made in comparing the results with the predictions of the proposed decay scheme; all significant differences are noted in the text. Intensities given for γ ray No. 5 reflect only the peak areas; they do not include allowance for the fact that the half-life for emission of No. 5 is long compared to the resolving times employed (see text).

[c] Statistical errors are less than 15% of the intensities, unless noted. The values are averages of experiments with 5.1-cm×5.1-cm and 7.6-cm×7.6-cm NaI(Tl) detectors; the crystal size made little difference.

[d] Statistical uncertainties (σ) are about 25% of the indicated intensities.

[e] Selected sums correspond to 1010 to 1250 keV.

[f] Selected sums correspond to 600 to 750 keV.

[g] Selected sums correspond to 510 to 620 keV; this range selects both 670.0-to-115.6 and 567.7-to-0 cascades. Significant contributions from 670.0-to-0 cascades are also seen.

[h] We indicate the degree of confidence with which we can attribute a given γ ray to the decay of ^{107}Rh. Where the transition has been placed in the ^{107}Pd level scheme, the initial and final states are indicated in parentheses.

[i] Observed intensities of these γ rays are consistent with the observed chance-coincidence intensities.

[j] Seen with NaI(Tl) detectors.

[k] Range of possible intensity of the cascades corresponding to the sum peak; the exact value depends on the energies of the component γ rays.

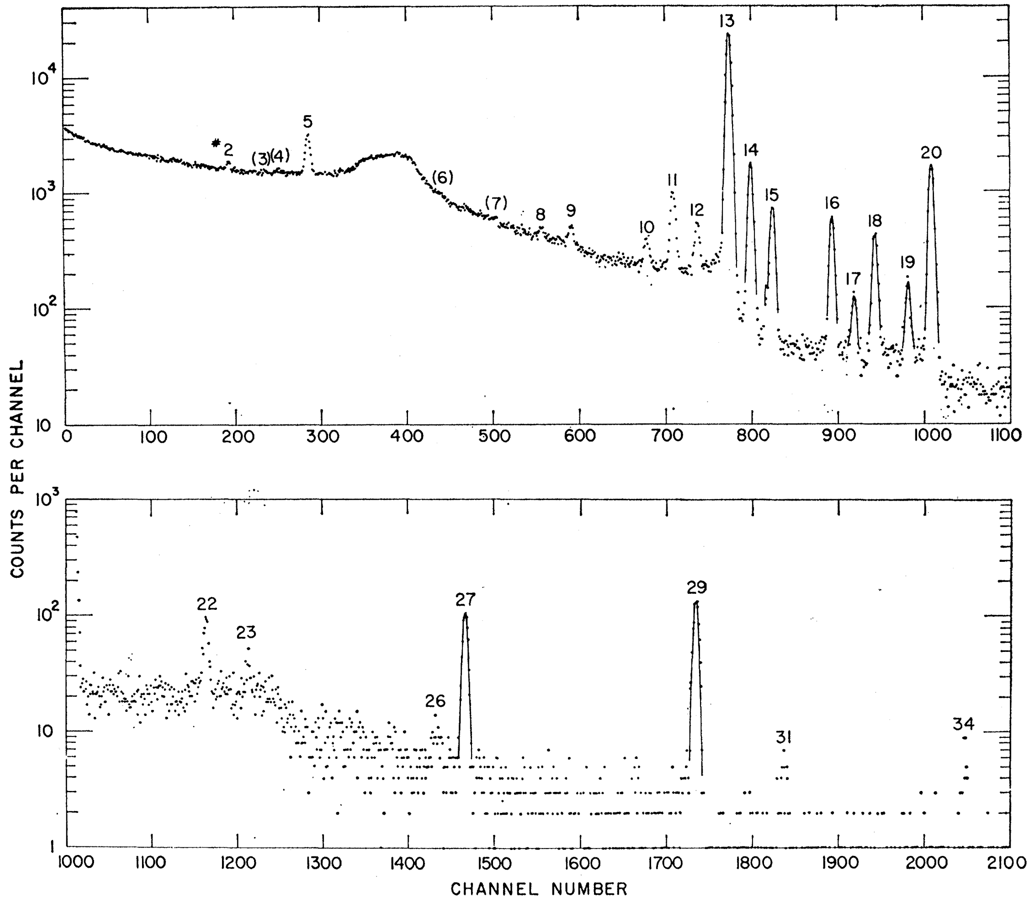

FIG. 1. γ-ray spectrum of ^{107}Rh. The detector was a 0.5-cm-thick$\times$4-cm^2 Ge(Li) diode. The source, mounted on a 547 mg cm^{-2} Be disk which served as a β absorber, was approximately 1.3 cm from the detector. For this spectrum the initial count rate was about 200 per sec. The spectrum was accumulated for 1000 sec, beginning 35 min after the end of irradiation. The energy scale corresponds to E (keV) $=6.43+0.3826\times$ (channel number). Numbers refer to γ-ray assignments from Table I. The shoulder on the left of No. 15 is due to 35.4-h ^{105}Rh.

which they refer, with the exception that three singles intensities (in parentheses in column 3) are based on coincidence measurements. No absolute intensities were determined in this work; the absolute intensities given in Table I are based on previously reported[1] absolute measurements. (See footnote to column 3.)

Classification. Each γ ray included in Table I was, in one or more of the types of measurements, at least twice as intense as the statistical uncertainty of the intensity. Those γ rays which (a) showed reproducible intensities in measurements of a given type, (b) could be observed in spectra taken over a period of time sufficient for a half-life confirmation, and (c) appeared in the various types of measurements in a manner consistent with their placement in the decay scheme, were classified as "definitely" associated with the decay of ^{107}Rh.

Singles measurements. Most of the data given in Table I, columns 2 and 3, for γ rays Nos. 2–40 were obtained from Ge(Li) spectra like those shown in Figs. 1 and 2. The spectra at once reveal the complexity of the ^{107}Rh decay scheme relative to that proposed previously,[1] a complexity now known to be typical of odd-A nuclei in this mass region.

The energy scales for the Ge(Li) singles spectra were obtained by the use of ^{22}Na, ^{51}Cr, ^{57}Co, ^{109}Cd, ^{137}Cs, ^{198}Au, and ^{203}Hg as energy standards.[14] First, spectra were obtained for a combination of ^{107}Rh and all of the above except ^{51}Cr and ^{203}Hg. These spectra allowed observation of the major γ rays of ^{107}Rh and simultaneous calibration of the scale. The large number of γ rays from ^{107}Rh in the range 250–400 keV prevented the use of standards in this range to detect any nonlinearities in the spectrometer system, so that the calibration in this range was obtained by the substitution of ^{51}Cr and ^{203}Hg for ^{107}Rh. The relative intensities of the standard

[14] We have used the energies compiled in Ref. 12 for all of the standards except ^{109}Cd. For ^{109}Cd (isomeric transition in ^{109}Ag), we used 88.033 keV [W. R. Pierson and R. H. Marsh, Nucl. Phys. **A104**, 511 (1967)].

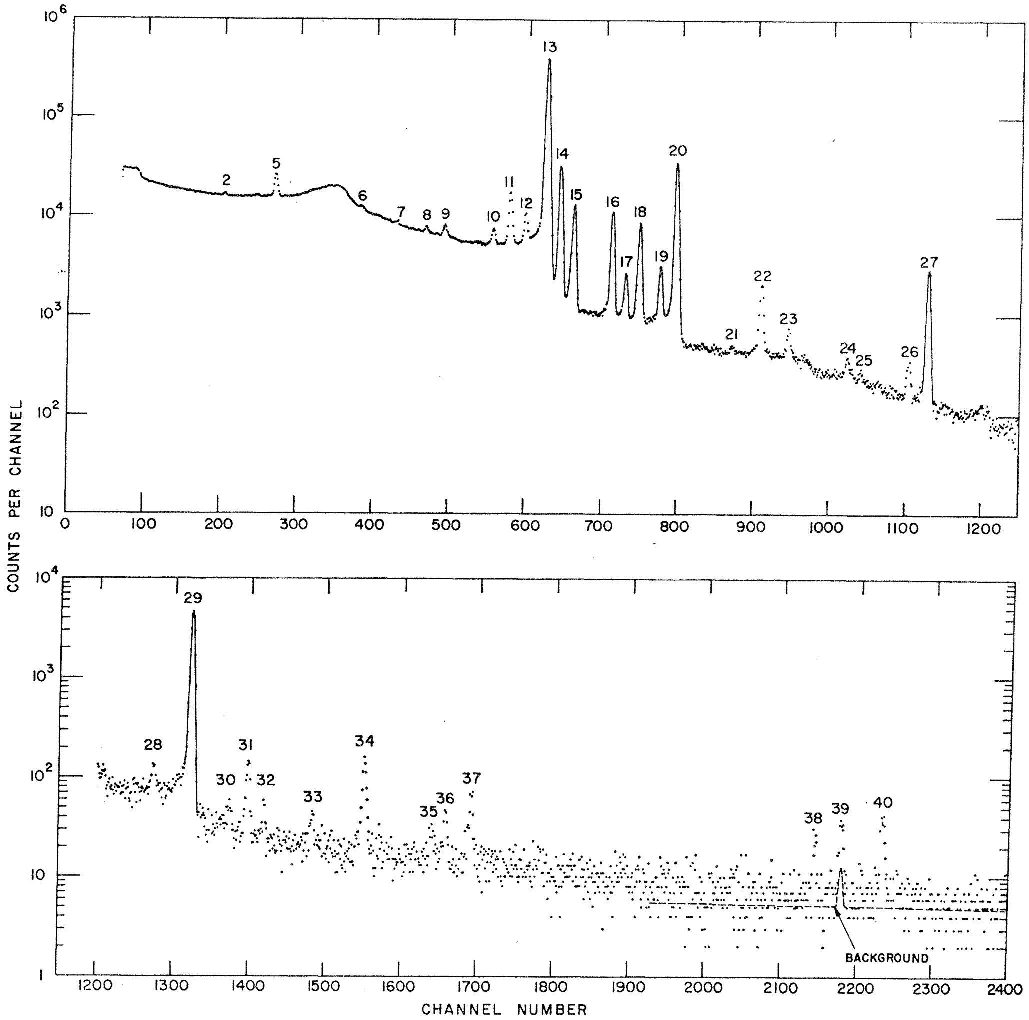

FIG. 2. γ-ray spectrum of ^{107}Rh. This is like Fig. 1 but with a 24-cm³ modified coaxial Ge(Li) diode. The source was mounted on a 547 mg cm^{-2} Be disk and was approximately 1.2 cm from the end of the detector. This is actually the combined spectra of two samples accumulated for 2000 sec each. The initial count rates were 305 and 365 per sec, beginning 39 and 41 min after the end of the irradiation. The dashed line indicates the approximate background spectrum in the energy region where its contribution is the most significant.

γ rays in the composite spectra were adjusted by selection of the positions of the individual sources. We found no indication of a dependence of the energy calibration on the source-to-detector distance (other than count-rate effects).

For each of the spectra the energy scale was determined by least-squares fits to polynomials. In general, linear fits were within 0.1 keV. The errors reflect an estimate of the over-all uncertainty of the energies; the true values lie within the indicated range with a high, but not precisely defined, degree of probability.

The intensities given in Table I, column 3 are based on relative intensities obtained by correction of peak areas for differences in peak efficiencies as already described. Intensities of γ rays Nos. 6, 7, 21, 23, 31–36, 38, and 40 include corrections arising from coincidence summing in the 24-cm³ Ge(Li) spectrum (Fig. 2).

The intensity errors quoted are *not over-all uncertainties*; they are typical peak-area errors inherent in the analysis of a good spectrum—that is, mainly statistical error, with a contribution from errors involved in curve peeling. When peak-area errors are not quoted, they are less than 7%. Not included are uncertainties in the relative-efficiency curves; for the Ge(Li) detectors, these uncertainties range from zero at 302.77 keV (the energy chosen for normalization) to possibly 20 or 30% at, respectively, the high- and low-energy extremes. Also not included is the normalization error of about 8% (see Ref. 1) in conversion to absolute intensities.

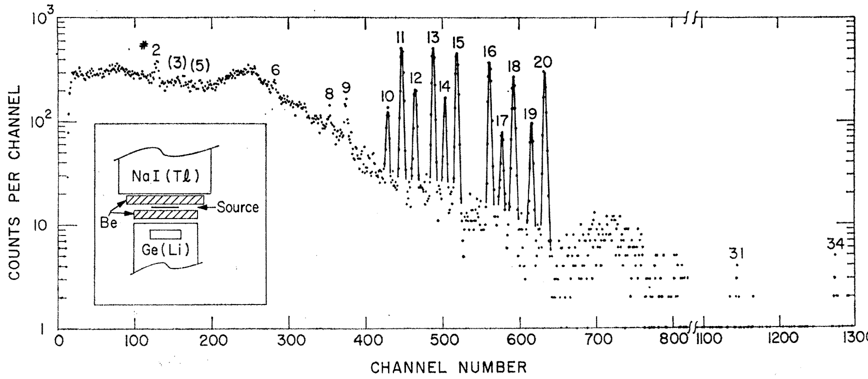

FIG. 3. Prompt $\gamma\gamma$ coincidence spectrum. The spectrum was taken from a 0.5-cm×4-cm² Ge(Li) detector in prompt coincidence (resolving time $\tau = 50$ nsec) with a 7.6-cm×7.6-cm NaI(Tl) detector. The discriminator in the NaI(Tl) channel was set to accept pulses corresponding to energies above 220 keV. The inset shows the arrangement of source and detectors, including Be to absorb β radiation.

Measurements of the low-energy region with the Si(Li) detector revealed no new radiations except the expected Pd K x rays (from internal conversion) and Rh K x rays (from excitation of the bulk rhodium and from ^{103m}Rh). The intensity of the Pd K x rays was established by determination of their intensity relative to that of γ ray No. 13 by means of calibrated NaI(Tl) detectors.

A shoulder at approximately 880 keV and a peak at about 1140 keV were observed with a 7.6-cm×7.6-cm NaI(Tl) crystal placed close to the source. These features can be assigned definitely to the decay of ^{107}Rh. The 1140-keV peak was found to vary with source-to-detector distance in a manner clearly characteristic of a coincidence-sum peak (that is, a level at about 1100 keV [15] depopulated mostly or entirely by γ-ray cascades). These observations corroborate those made in earlier work.[1] Presumably the shoulder at 880 keV consists of one or more of the γ rays Nos. 35, 36, and 37 resolved in the 24-cm³ Ge(Li) spectrum, so at least one of these three is definitely associated with ^{107}Rh decay even though we cannot say which one(s).

Prompt coincidences. The prompt-coincidence experiments sought to identify the γ rays which are involved in $\gamma\gamma$ cascades and to determine the relative intensities of the cascade components. In these experiments, spectra were obtained from a Ge(Li) detector operated in prompt coincidence with a NaI(Tl) detector. In one experimental arrangement, a 10-cm³ coaxial Ge(Li) detector and a 5.1-cm×5.1-cm NaI(Tl) detector were employed, with the latter accepting all pulses above noise. In another arrangement, that from which Fig. 3 was obtained, a different set of detectors was employed (see caption), with the threshold in the NaI(Tl) channel set to suppress Compton and backscatter events. Except for γ rays which were excluded in the latter case by the threshold, the results obtained from the two sets of apparatus are not significantly different. The intensities given in Table I, column 4 are the combined results of the various experiments.

As implied by the table, most of the γ rays seen in these spectra are recognizable as γ rays already seen in singles spectra. The relations $E_{11}+E_{20}=E_{12}+E_{19}=E_{13}+E_{18}=E_{14}+E_{17}=E_{15}+E_{16}=E_{29}$ point to the existence of a ^{107}Pd level at about 670 keV, γ ray No. 29 being the crossover transition.

Table I shows that γ rays Nos. 13, 14, and 20 are much stronger in singles than in coincidence spectra, and therefore must *follow* their partners in their respective cascades. This, together with the fact that these are by far the three strongest transitions in the singles spectrum, establishes levels at 302.8, 312.2, and 392.5 keV.

Delayed coincidences. Prominent γ rays which are missing (or most strongly suppressed) in the prompt-coincidence spectrum are Nos. 5, 22, 27, and 29. The absence of No. 29 is understandable from what has just been said. The sum $E_5+E_{22}=E_{27}$ points to a level at 567.7 keV depopulated by transitions to the ground state and to a long-lived level at 451.9 or 115.6 keV; this inference combines with the relations $E_5+E_9+E_{15}=E_5+E_{10}+E_{12}=E_{29}$ to indicate that the long-lived level is the already-known[3] $J\pi=\frac{1}{2}+$ level at about 115 keV. (γ ray No. 22 then represents the transition to this level from the level at 567.7 keV.)

A Ge(Li) spectrum in coincidence with delayed NaI(Tl) pulses verified that γ ray No. 5 is delayed, the intensity suggesting a half-life of about a microsecond. A spectrum of delayed Ge(Li) pulses in coincidence with NaI(Tl) pulses (Fig. 4) showed that the γ rays Nos. 9, 10, 12, 15, and 22 (Table I, column 5) participate in populating the 115.6-keV level. The intensities (not normalized) relative to singles indicated a half-life of 400–1200 nsec.

Sum coincidences. Among the levels thus far indicated are those at 567.7, 670.0, and approximately 1100 keV. The purpose of the sum-coincidence experiments was to learn which cascades are involved in deexcitation of these levels.

The experiments employed a 0.5-cm×4-cm² Ge(Li)

[15] Because of the nonlinearity of NaI(Tl), a sum peak has an apparent energy slightly higher than the correct one; see J. Kantele and R. W. Fink, Nucl. Instr. Methods 13, 141 (1961).

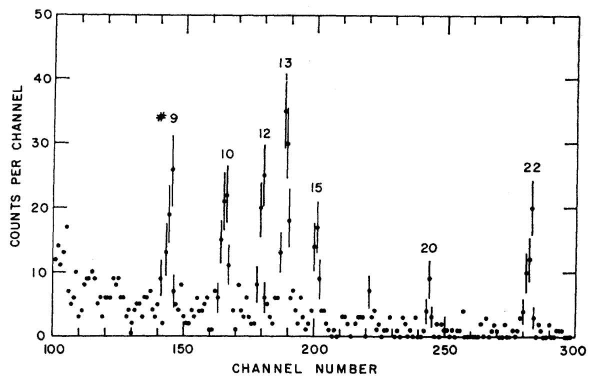

FIG. 4. Spectrum of γ rays feeding the 115.6-keV transition. This spectrum was obtained from a 10-cm^3 coaxial Ge(Li) detector in delayed coincidence with pulses corresponding to 85–170 keV from a 0.3-cm-thick×2.9-cm-diam NaI(Tl) detector. The configuration of source and detectors was similar to that shown in Fig. 3. The coincidence criterion corresponded to events in the NaI(Tl) detector which were delayed by 200–800 nsec relative to those in the Ge(Li) detector. All of the intensities of γ rays Nos. 13 and 20 can be attributed to chance coincidences.

detector, a 7.6-cm×7.6-cm NaI(Tl) detector, and a linear adding network.[16] The amplified outputs of the two detectors were adjusted to have the same gain (pulse height versus energy at $\approx$500 keV). Each amplifier output was fed into the adding network. The output of the adding network was fed, together with the two amplifier outputs, into a threefold fast-slow coincidence sorter. Suitable delays were used at various points to produce proper pulse timing. Pulses from the Ge(Li) detector were recorded whenever there was a triple coincidence ($\tau\approx$180 nsec) between pulses from the two detectors and pulses of specified amplitude from the adder output. With this logic one expects to observe primarily the components of two-member cascades. The crossover should produce a continuum with broad maxima at energies corresponding to the Compton edge and backscatter. Components of three-member cascades should appear only when two members are detected as full-energy events in the NaI(Tl) detector. For the geometry of these experiments, three-member cascades have efficiencies of 0.2–0.4 relative to those for two-member cascades.

The spectra obtained from these experiments are given in Figs. 5 and 6 and the results are summarized in Table I. For the $\approx$1100-keV sum, at least four components can be identified, namely, γ rays Nos. 14, 20, 31, and 34 (Fig. 5 and Table I, column 6). These correspond to cascade energies of 1102 keV. Since the lower-energy members have been identified as ground-state transitions, these data indicate a level at 1102 keV. There is a hint of a cascade involving γ rays of 382 and 720 keV, but the statistical uncertainties are quite large.

The γ rays seen in the 670-keV cascades (top part of Fig. 6 and Table I, column 7) can be identified with γ rays seen in singles spectra, but Nos. 4 and 7 are seen here perhaps more clearly than anywhere else. The sums corresponding to $\approx$560 keV (554-keV cascades between the 670.0- and 115.6-keV levels and 568-keV cascades from the 567.7-keV level to the ground state) are shown in the bottom part of Fig. 6. In interpreting these spectra, it is necessary to realize that a significant fraction of the 670-keV cascade components (20%, more or less, depending on the energies of the components) is detected in the 560-keV sum measurements. Thus, when the possibility of significant contributions from higher-energy cascades exists, experiments of this type may yield only qualitative results.

C. Properties of 115.6-keV Transition

Conversion coefficient (α_K). The conversion coefficient was determined from the NaI(Tl) spectrum in delayed coincidence with the 451.9-keV γ ray. The rationale for this procedure is that the NaI(Tl) spectrum of transitions from the 115.6-keV level should consist of (a) the 115.6-keV γ ray and (b) K x rays from internal conversion of the 115.6-keV transition. These radiations can be made to stand out by delayed-coincidence gating on a γ ray feeding the 115.6-keV level.

For gating, the 451.9-keV is the most suitable γ ray because it accounts for about one-third of the γ-ray

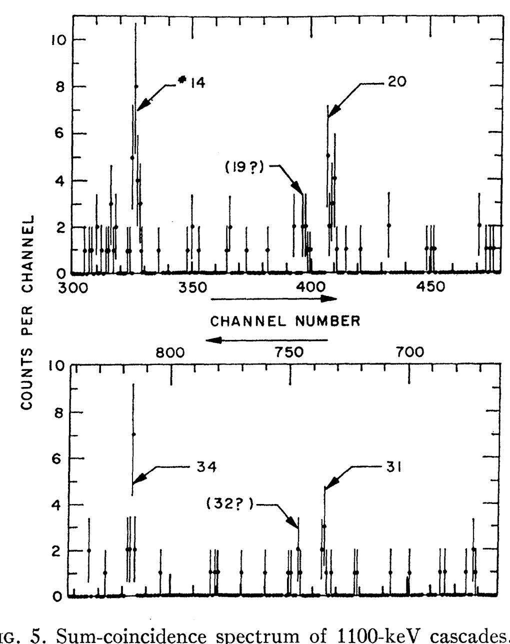

FIG. 5. Sum-coincidence spectrum of 1100-keV cascades. The spectrum from the Ge(Li) detector (0.5 cm×4 cm^2) is given for events which correspond to a sum of 1010 to 1250 keV for $\gamma\gamma$ coincidences between the Ge(Li) detector and a NaI(Tl) detector (7.6 cm×7.6 cm) (see text). The configuration of source and detectors was the same as that used for the prompt-coincidence measurements (Fig. 3). Note that the abscissa for the lower plot is reversed in order to show the relation of Nos. 34 to 14 and of Nos. 31 to 20.

[16] C. M. Kukla, Rev. Sci. Instr. 40, 598 (1969).

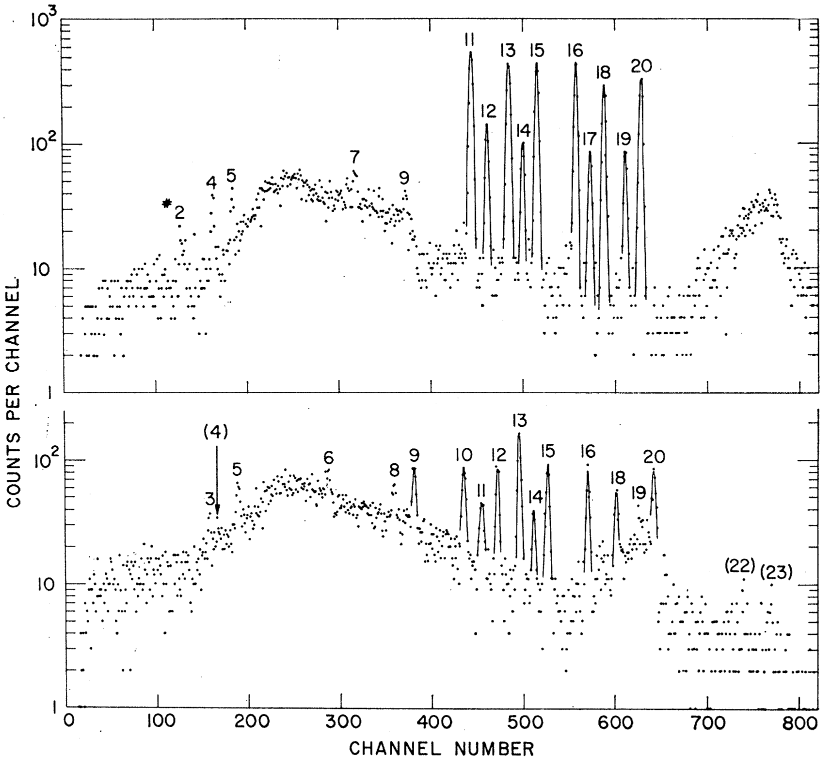

FIG. 6. Sum-coincidence spectra of 670-keV cascades (upper), and of 554- and 568-keV cascades (lower), obtained with 0.5-cm×4-cm² Ge(Li) in coincidence with 7.6-cm×7.6-cm NaI(Tl). The upper spectrum corresponds to events which satisfied a sum restriction of 600–750 keV; the peak labeled 9 is spurious, as shown by further measurements of this kind (see text). The lower curve corresponds to a sum of 510–620 keV, that is, to cascades between the 567.7-keV level and the ground state and between the 670.0-keV and 115.6-keV levels, and includes contributions from higher-energy cascades. Note that the energy scales are slightly different. The configuration of source and detectors is given in Fig. 3.

intensity populating the 115.6-keV level, it is not involved in significant prompt cascades, and it lies in an energy region which happens to be relatively free of other γ rays. Figure 7 shows the spectrum obtained with a thin-window NaI(Tl) crystal in delayed coincidence

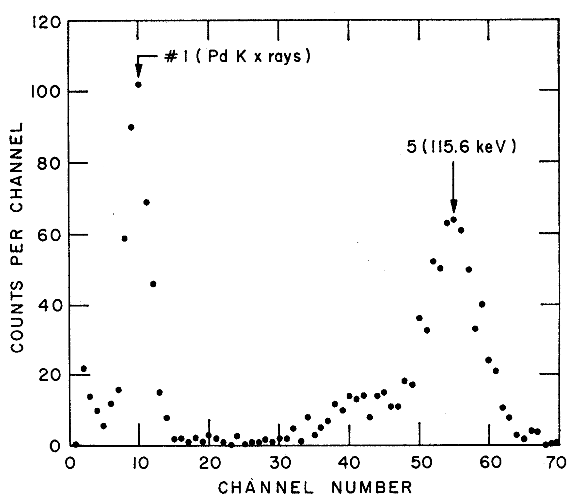

FIG. 7. NaI(Tl) spectrum of radiations in delayed coincidence with the 451.9-keV γ ray. The spectrum consists of Pd K x rays (internal conversion) and γ rays emitted in the decay of the 115.6-keV level. These radiations were detected in a 0.3-cm-thick × 2.9-cm-diam NaI(Tl) detector (entrance window 0.0025 cm Al) in delayed coincidence (100 to 1000 nsec) with 420- to 500-keV events in a 5.1-cm×5.1-cm NaI(Tl) detector. Both detectors were covered with Be to absorb β rays and conversion electrons. The configuration of source and detectors was similar to that given in Fig. 3.

with pulses in the 420- to 500-keV region. By means of calibrated ^{109}Cd and ^{57}Co sources, the intensity of the Pd K x rays relative to that of the 115.6-keV γ ray was found to be 0.56±0.06. This ratio, together with a K-shell fluorescence yield of 0.81±0.02 as suggested by the recent literature,[17,18] leads to the K-shell conversion coefficient

$$(\alpha_K)_{115.6}=0.70\pm0.09.$$

This value is in good agreement with the theoretical value (0.66) for $E2$,[19] the type of transition expected ($\frac{1}{2}+\rightarrow\frac{5}{2}+$). The total conversion coefficient ($\alpha_K+\alpha_L+\alpha_M$), calculated from the experimental α_K (above) and theoretical[19] α_L and α_M, is 0.88±0.10, implying a total intensity ($\gamma+e$) of 0.98% for the 115.6-keV transition.

Half-life. The cascade used to measure the conversion coefficient was also used to measure the half-life of the 115.6-keV level. Time delays between the members of the cascade were measured with a time-to-amplitude converter (TAC). The sample for these measurements was prepared by fission of natural uranium with 42-MeV ^{4}He ions. Ruthenium was separated from the

[17] A. H. Wapstra, G. J. Nijgh, and R. van Lieshout, *Nuclear Spectroscopy Tables* (North-Holland Publishing Co., Amsterdam, 1959).

[18] R. W. Fink, R. C. Jopson, H. Mark, and C. D. Swift, Rev. Mod. Phys. **38**, 513 (1966); E. J. Callan, Bull. Am. Phys. Soc. **7**, 416 (1962); E. J. Callan, in *Proceedings of the International Conference on the Role of Atomic Electrons in Nuclear Transformations, Warsaw, 1963* (Polish Academy of Science, Warsaw, 1963); C. Foin, A. Gizon, and J. Oms, Nucl. Phys. **A113**, 241 (1968).

[19] R. S. Hager and E. C. Seltzer, Nucl. Data **A4**, 1 (1968).

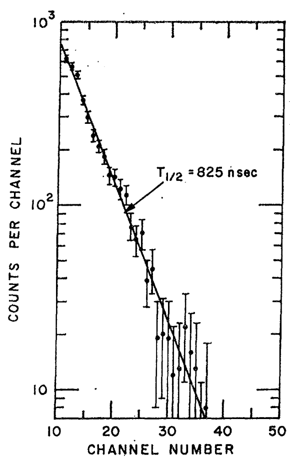

FIG. 8. Decay curve for the 115.6-keV state. Time delays between population of the 115.6-keV level by a 451.9-keV γ ray and decay to the ground state by γ-ray emission were measured in a time-to-amplitude converter. "Start" pulses originated from a 7.6-cm$\times$ 7.6-cm NaI(Tl) detector and a single-channel analyzer which selected events corresponding to approximately 450 keV. The "stop" pulse came from events of approximately 116 keV observed in a 3.5-cm-diam$\times$ 2.5-cm-thick NaI(Tl) detector. The chance-coincidence background (83 counts per channel) has been subtracted from the data points. The horizontal scale is 41.6 nsec per channel.

target and the other fission products by distillation from perchloric acid. After a period for growth of rhodium, ruthenium was removed by fuming from perchloric acid, and rhodium was coprecipitated with iron hydroxide.

Several TAC spectra were obtained over a period of approximately 90 min; these were analyzed to confirm that the observed delayed coincidences corresponded to a half-life of 22 min. The TAC spectrum from an intermediate count is given in Fig. 8. The sample strength at the time this spectrum was obtained gives a good compromise between chance rate and net statistics. The TAC was calibrated with ^{85}Sr (K x ray followed by 513-keV γ ray; $T_{1/2}=980$ nsec[20]) and calibrated delay lines.

The half-life of the level was found to be 850 ± 100 nsec from an analysis of the results of the several spectra obtained with a single sample.

D. Decay Scheme

We have already seen that the results imply levels in ^{107}Pd at 0, 115.6, 302.8, 312.2, 392.5, 567.7, 670.0, and 1102 keV. Thus far we have placed γ rays Nos. 5, 11, 13, 14, 17, 18, 20, 22, 27, 29, 31, and 34 as transitions among these levels (Fig. 9).

According to our placement, γ rays Nos. 11, 18, and others are wholly involved in prompt cascades (that is, always in prompt coincidence with one or more other γ rays). Such γ rays should have approximately [not exactly, because of the energy dependence of the NaI(Tl) efficiency for the postulated coincidence partners] the same intensity in column 4 of Table I as in column 3—or greater intensity if the cascades have more than two members. Accordingly, the near-equality between columns 3 and 4 of Table I with respect to the intensities of γ rays Nos. 11 and 18 indicates that the normalization between the two columns has been properly chosen. γ rays which then appear to be wholly involved in prompt cascades are Nos. 2, 6, 8–12, 15–19, 31, and 34; No. 3 might well be in this category, too. Similarly, in delayed coincidence, γ rays that are always followed eventually by the 115.6-keV transition (including internal conversion) should have the same intensity as in singles if the proper normalization is chosen. This category would include Nos. 9, 10, and 22; the others seen in delayed coincidence, namely, Nos. 12 and 15, would seem to be in paths that lead in part to levels other than 115.6 keV.

The relation $E_2+E_{14}=E_{20}$ places γ ray No. 2 between the 392.5- and 312.2-keV levels, a placing confirmed by the intensity of No. 2 in the prompt-coincidence spectrum. The occurrence in the 670-keV sum-coincidence spectrum is a consequence of the fact that it is in a low-intensity three-member cascade from the 670.0-keV level.

The relation $E_4+E_{27}=E_{29}$ places γ ray No. 4 between the 670.0- and 567.7-keV levels. It is at about the limit of detectability in the prompt-coincidence spectrum and thus our failure to see it there is not surprising. One would also not expect to be able to see the partner (No. 27) in the prompt-coincidence spectrum, especially in the case where the NaI(Tl) threshold was set at 220 keV; if No. 27 were present, as might be the case (Table I), this would imply population of the 567.7-keV level by undetected transitions. In any event, γ ray No. 4 does appear as expected in the 670-keV sum, in confirmation of its placing.

The relation $E_6+E_{20}=E_{27}$ places No. 6 between the 567.7- and 392.5-keV levels. In this case No. 6 would be expected in the 560-keV sum-coincidence spectrum with about the same intensity as in the prompt-coincidence spectrum, and this expectation is fulfilled.

The relations $E_8+E_{16}=E_{27}$ and $E_{15}+E_{16}=E_{29}$ indicate a level at 348.2 keV populated by γ rays Nos. 8 and 15 from, respectively, the 567.7- and 670.0-keV levels. This seems to be confirmed by the intensities of Nos. 8, 15, and 16 in the prompt-coincidence spectrum and in the 560- and 670-keV sum-coincidence spectra. (The abundance of Nos. 15 and 16 in the 560 sum is due mostly to the earlier-mentioned experimental impossibility of cleanly selecting 560 sums without an admixture of events associated with 670 sums.)

Once the level at 348.2 keV is established, γ ray No. 9 can be placed as a transition between the 348.2- and 115.6-keV levels. This is consistent with the intensity of No. 9 in the prompt-coincidence spectrum and seems to be confirmed by the presence of Nos. 9 and 15 and the absence of No. 16 in the delayed-coincidence spectrum; the intensities of Nos. 9 and 15 should be equal in the delayed-coincidence spectrum and are not, but the disparity is not statistically significant. This placing of No. 9 is also consistent with its intensity in the 560-keV sum-coincidence spectrum and its absence from the 670-keV sum-coincidence spectrum. (A peak at about

[20] K. E. G. Löbner, Nucl. Phys. 58, 49 (1964).

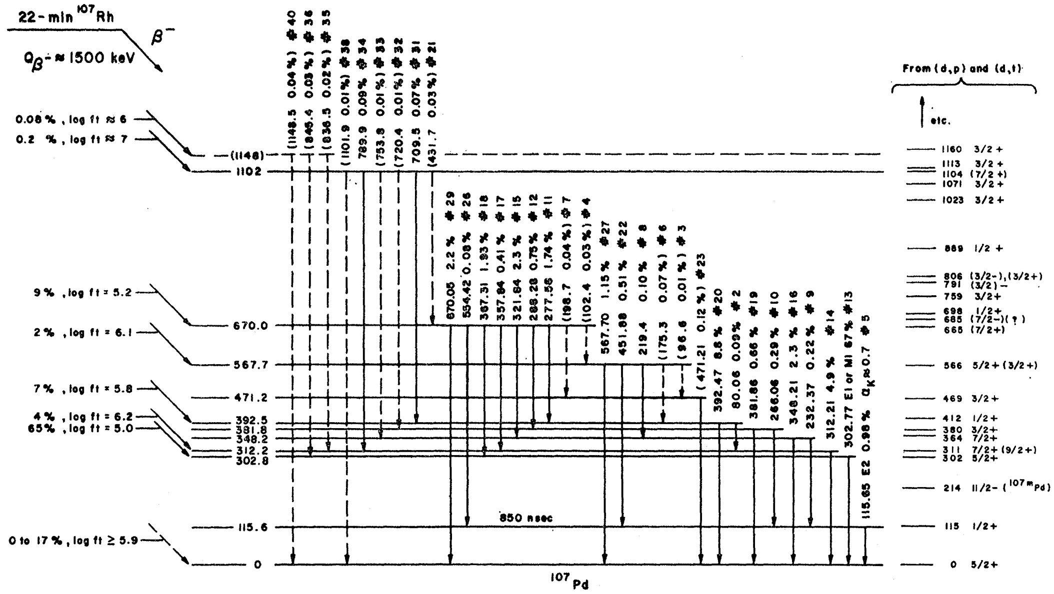

FIG. 9. Decay scheme of ^{107}Rh. For each γ transition shown, we give its energy in keV, its intensity in percent, and the number by which it is denoted in the text and in Table I, column 1. Intensities of γ transitions include internal conversion (see text) and are put on an absolute basis as specified in footnote a of Table I. Transitions Nos. 24, 25, 28, 30, 37, and 39 have not been placed. The placings of Nos. 21, 26, 33, 35, and 36 are based only on energy balances. Dotted lines are transitions classified as "probable" or "possible." Levels observed in (d, p) and (d, t) spectroscopy (Refs. 2–4) are shown for comparison.

232 keV appears in the 670-keV sum-coincidence spectrum given in Fig. 6, but further measurements show that this is spurious, possibly a contaminant; other instances can be cited in which a sample seemed to contain an impurity with a γ ray at 232 keV.)

The relations $E_5+E_{10}=E_{19}$ and $E_{12}+E_{19}=E_{29}$ indicate a level at 381.8 keV populated by γ ray No. 12. The prompt-coincidence, sum-coincidence, and delayed-coincidence intensities are all consistent with this arrangement.

The relations $E_3+E_{23}=E_{27}$ and $E_7+E_{28}=E_{29}$ indicate a level at 471.2 keV populated by γ rays Nos. 3 and 7 from, respectively, the 567.7- and 670.0-keV levels, and depopulated by No. 23 to the ground state. The 560-keV sum results bear out the No. 3–No. 23 cascade. In the 670-keV sum-coincidence spectrum (Fig. 6) No. 7 can be seen and this tends to confirm the No. 7-No. 23 cascade; although the partner cannot be seen in this case, the expected intensity is about at the detection limit. Prompt-coincidence spectra show No. 3 as expected, and a hint of No. 7 but, again because of the low intensity, no No. 23.

In accordance with the relation $E_5+E_{26}=E_{29}$, we place No. 26 between the 670.0- and 115.6-keV levels. Presumably, No. 26 was not observed in coincidence spectra because of its low intensity and the long half-life of the 115.6-keV level.

The placings of Nos. 31 and 34 from the 1102-keV level have already been discussed. The intensities of the four γ rays in the 1100-keV sum-coincidence spectrum (Table I, column 6) are consistent with this placement if, in comparing column 6 with column 3, one remembers that the intensities of γ rays in the Ge(Li) sum-coincidence spectrum are affected by the NaI(Tl) efficiencies of their partners. Although No. 14 is less intense than expected, the observed intensity is within the statistical uncertainties.

On the basis of the relations $E_{16}+E_{33}=E_{19}+E_{32}=E_{21}+E_{29}=E_{38}$, γ rays Nos. 38, 33, 32, and 21 are placed between the 1102-keV level and, respectively, the 0-, 348.2-, 381.8-, and 670.0-keV levels. There is a hint of the No. 19-No. 32 cascade in the sum-coincidence spectrum in Fig. 5, but all three cascades are really too weak to be expected to show.

The relations $E_{13}+E_{36}=E_{14}+E_{35}=E_{40}$ imply a level at 1148 keV, γ rays Nos. 40, 36, and 35 being transitions to levels at, respectively, 0, 302.8, and 312.2 keV. The two cascades No. 13-No. 36 and No. 14-No. 35 might be responsible for some of the counts in the regions corresponding to Nos. 13 and 14 in Fig. 5; the seeming absence of Nos. 35 and 36 would be consistent with the low Ge(Li) efficiency.

Most of the area of the 1100-keV peak seen in the NaI(Tl) spectrum obtained at high geometrical efficiency corresponds to coincidence sums from $\gamma\gamma$ cascades. The aggregate cascade intensity implied by this peak area depends on the energies of the components. Given the identity of the components as determined by Ge(Li) measurements (shown in Table I and Fig. 9), and with allowance for the contribution of

γ rays in the 1100-keV region (Nos. 38, 39, 40), the area of the NaI(Tl) peak would imply a cascade intensity of 0.2%. This is only slightly more than the combined intensities of Nos. 31 and 34, and indicates that the two observed cascades, together with the less well-established ones and the crossovers, can account for all of the depopulation of the 1102- and 1148-keV levels.

Figure 9 was constructed from the foregoing data with allowance for internal conversion. The conversion coefficient for γ ray No. 5 was estimated in the manner already described. For the others, a multipolarity $M1$ was assumed.

Figure 9 shows γ ray No. 13 as being dipole. The evidence is as follows: The K x rays associated with internal conversion of the 115.6-keV transition (about 0.56 times the intensity of the γ ray itself, as noted above, or approximately 0.29% of the ^{107}Rh disintegrations) can be subtracted from the total Pd K x-ray intensity to give a remainder of 0.87% as the maximum K x-ray intensity attributable to internal conversion of all other transitions including, of course, No. 13. This, together with the expected K-shell fluorescence yield,[17,18] leads to an upper limit of $\alpha_K \leq 0.016$ for the 302.8-keV transition, compatible only with dipole character.[19]

Given the γ-transition intensities, with allowance for internal conversion, the β intensities to the various ^{107}Pd levels can be deduced on the basis of intensity balances. The intensity derived for the β transition to the ground state is particularly sensitive to the γ-transition intensity values, and this is reflected in the range of values shown in Fig. 9 for the ground-state β transition. The log ft values shown in Fig. 9 were obtained with the aid of nomograms.[21]

The 21-sec isomer ^{107m}Pd does not seem to be formed in ^{107}Rh decay ($<0.2\%$, as estimated from our spectrum together with the published[22] α_K of the isomeric transition). From fast-neutron-bombarded Pd and ^{108}Pd we have verified that the energy of the transition is 214 ± 1 keV, in agreement with the value from Ref. 3.

III. DISCUSSION

First, a limited amount of information can be surmised about spins and parities. Beginning with the $\frac{5}{2}+$ ground state (this $J\pi$ assignment seems fairly secure[2,3,23]) and the $J\pi = \frac{1}{2}+$ level at 115.6 keV, we infer that the spins of the 348.2-, 381.8-, and 567.7-keV levels probably are no greater than $\frac{5}{2}$, since one would not normally expect γ-ray transitions of order octupole or higher (to the 115.6-keV level) to compete strongly with transitions of lower order (to the ground state).

Levels which do not seem to depopulate to the 115.6-keV level probably have high spins ($\geq \frac{5}{2}$); this includes the 302.8-, 312.2-, and 392.5-keV levels. The 1148-keV level is shown as depopulating mainly to levels in the latter category and, consequently, it probably has a high spin. The 670.0-keV level depopulates to essentially everything beneath it and probably has a spin close to $\frac{5}{2}$ (not exceeding this if γ ray No. 26 is properly placed in Fig. 9). By the same token, the spin of the 1102-keV level is probably close to $\frac{5}{2}$.

The probable spin of the 567.7-keV level ($\leq \frac{5}{2}$) and the logft for the β transition to it indicate a spin not larger than $\frac{7}{2}$ for ^{107}Rh. On the other hand, β transitions to the 115.6-keV level do not seem to be significant ($<0.5\%$, log$ft > 7.4$), so the ^{107}Rh spin is probably at least $\frac{5}{2}$. Of the two alternatives $\frac{5}{2}$ and $\frac{7}{2}$, the latter is preferred because direct β decay seems to avoid the numerous $\frac{3}{2}$ levels in ^{107}Pd (Fig. 9). An even parity is suggested by the logft values, if the ^{107}Pd levels are predominantly of even parity as is reported.[2,3] If ^{107}Rh is $\frac{7}{2}+$, the β transition intensity to 21-sec ^{107m}Pd should be about 0.013%.

If we now compare the above conjectures with the levels reported from (d, p) and (d, t) spectroscopy[2–4] as indicated in Fig. 9, we find that several levels in ^{107}Rh decay can be identified (by their energies and possible spins) with levels reported in one or more of the reaction papers; these are the levels at 0, 115.6, 302.8, 312.2, 381.8, 471.2, 567.7, 670.0, and 1102 keV. On the other hand, at least three levels are seen only in ^{107}Rh decay (348.2, 392.5, and 1148 keV) and several are seen only in the reactions (364, 412, and some at higher energies). A certain lack of overlap is to be expected since, for example, the (d, p) reaction can lead to low-spin states not accessible to β decay from a high-spin nucleus. However, there are observed in the neutron-transfer reactions a number of levels which, insofar as spins and parities are concerned, would be accessible by allowed β transitions from a nucleus with $J\pi = \frac{5}{2}+$ or $\frac{7}{2}+$. These levels include those at excitation energies of 0, 302, 311 (if $\frac{7}{2}+$), 364, and 665 keV. The general trend apparently is for β-decay probabilities to be low if spectroscopic factors are large. This trend is demonstrated by Table II. The 393- and 670-keV levels are particularly prominent in β decay and are not observed in the (d, p) reactions.

The $\frac{7}{2}+$ level at 364 keV reported in Refs. 3 and 4 should probably be populated in ^{107}Rh decay, by γ cascades if not by β transitions. The likelihood that a 364-keV γ transition could have been obscured by γ ray No. 18 seems remote, since no broadening of the peak of No. 18 was seen (Fig. 1).

With regard to the 115.6-keV level, it might be mentioned that the lifetime found agrees with the single-particle estimate[17] for a $\frac{1}{2}+ \to \frac{5}{2}+$ transition. This lends support to the evidence from (d, p) and (d, t) cross sections[2,3] that this level, like the 344-keV $J\pi = \frac{1}{2}+$ level in ^{105}Pd, has strong single-particle properties.

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[21] R. I. Verrall, J. C. Hardy, and R. E. Bell, Nucl. Instr. Methods **42**, 258 (1966). Their nomograms can also be found in Appendix IV of Ref. 12.

[22] W. Weirauch, Z. Physik **181**, 273 (1964).

[23] *Nuclear Data Sheets*, compiled by K. Way *et al.* (Printing and Publishing Office, National Academy of Sciences—National Research Council, Washington, D.C., 1961), NRC 61-4-18.

TABLE II. Comparison of β decay and neutron transfer to ^{107}Pd levels.[a]

Levels populated in β decay of ^{107}Rh			Levels populated in $^{106}Pd(d, p)$[b]		
Energy (keV)	Net β intensity (%)[c]	Normalized β intensity[d]	Energy (keV)	Assigned spin	Spectroscopic factor
0	(≤17)	(≤7)	0	5/2+	0.21
115.6	−0.1±0.2	≤0.04	115	1/2+	0.39
(214)	not seen	···	214	11/2−	0.29
302.8	65±10	≡65	302	5/2+	0.010
312.2	4.3±0.7	4.3	311	7/2+ (9/2+)	0.26
348.2	0.1±0.5	0.1		not reported	
(364)	not seen	···	364	7/2+	0.45
381.8	0.2±0.2	0.2	380	3/2+	0.29
392.5	7.0±1.4	9		not reported	
(412)	not seen	···	412	1/2+	0.041
471.2	0.06±0.02	0.1	469	3/2+	0.14
567.7	1.8±0.3	4.5	566	5/2+ (3/2+)	0.058(0.011)
670.0	9.5±1.4	40		not reported[e]	
(685)	not seen	···	685	(7/2−) (?)	0.0072

[a] Only levels up to about 700 keV are listed. No level corresponding to our 1102-keV level was seen in the high-resolution (d, p) work (Ref. 3), although a level at 1104 keV ($\frac{7}{2}+$) was reported in earlier $^{108}Pd(d, t)$ studies (Ref. 2).

[b] Data taken from Ref. 3.

[c] The intensities are the β intensities to the levels calculated from the intensity balance of the γ transitions. The errors are based on an assumed error of 15% in the total γ intensities in and out of the level. These errors give a qualitative indication of the reliability of the derived β intensities.

[d] Net β intensities have been normalized to the intensity of the β transition to the 302.8-keV level by removal of the energy dependence of the transition rates (from nomograms of logft values given in Ref. 21). Dependences on spin and parity remain.

[e] A level at ≈665 keV was observed in (d, t) reactions (Ref. 2) but with energy resolution too poor for correlation with levels observed in the decay scheme.

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