Beta- and Gamma-Ray Spectra of Pd^{111}†

WILLIAM W. PRATT
Department of Physics, The Pennsylvania State University, University Park, Pennsylvania

AND

ROBERT G. COCHRAN*
College of Engineering and Architecture, The Pennsylvania State University, University Park, Pennsylvania

(Received January 6, 1960)

Beta rays of 2.18 Mev and gamma rays of 0.377, 0.580, 0.620, 0.810, 1.380, and 1.450 Mev were found in the decay of the 22-minute isomer of Pd^{111}. Beta rays of 2.02 Mev and gamma rays of 0.170 and 1.690 Mev were found associated with the 5.5-hour isomer. Although the beta-ray groups may both represent the decay of the 22-minute state, the dissimilarity of the gamma-ray spectra implies some degree of beta-ray branching from the 5.5-hour state.

I. INTRODUCTION

THE beta- and gamma-ray spectra associated with the 22-minute and 5.5-hour isomers of Pd^{111} have been studied by McGinnis,[1,2] who found a 2.15-Mev beta ray and a 170-kev isomeric transition associated with the 5.5-hour isomer, and a 2.15-Mev beta ray followed by 60-kev conversion electrons associated with the 22-minute isomer. We report here the results of additional beta and gamma-ray measurements employing scintillation spectrometer techniques previously described.[3]

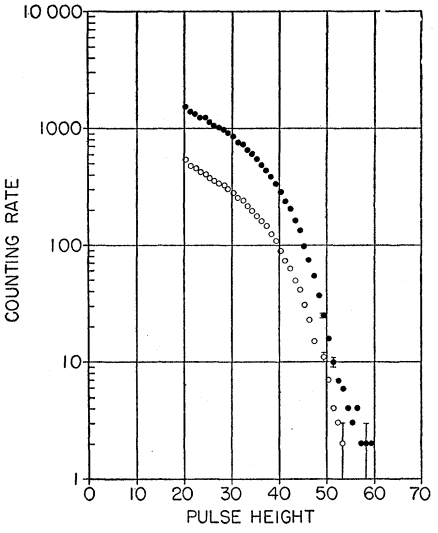


FIG. 1. Beta-ray spectra 30 minutes (solid circles) and 68 minutes (open circles) after exposure.

II. PROCEDURE AND RESULTS

Samples of Pd metal, enriched[4] to 91.4% in the isotope Pd^{110}, were exposed to thermal neutrons in the Pennsylvania State University research reactor. The Pd^{111} activity thus produced was studied by means of plastic phosphor and NaI scintillation spectrometers.

Figure 1 shows beta-ray spectra observed 30 minutes and 68 minutes after an exposure of 20 minutes. The energy range covered by the experimental points extends from 0.97 Mev to 2.50 Mev. The decrease of counting rate with time is substantially the same for all parts of the spectrum and is closely characteristic of the 22-minute half-life associated with the Pd^{111} ground state. The end point of the spectrum obtained from a Fermi plot is 2.18±0.10 Mev. Figure 2 shows beta-ray spectra observed 10 hours and 32 hours after an exposure of 20 minutes. The energy range extends

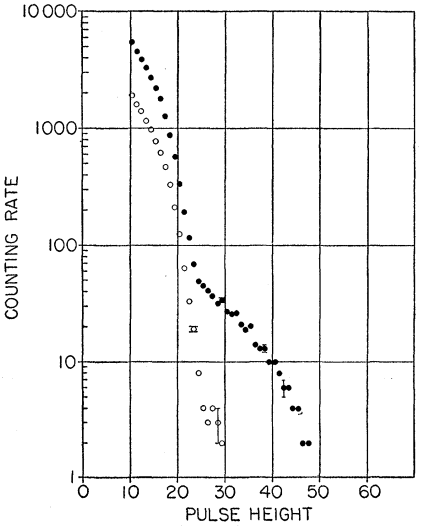


FIG. 2. Beta-ray spectra 10 hours (solid circles) and 32 hours (open circles) after exposure.

† This work was supported in part by a grant from the National Science Foundation.

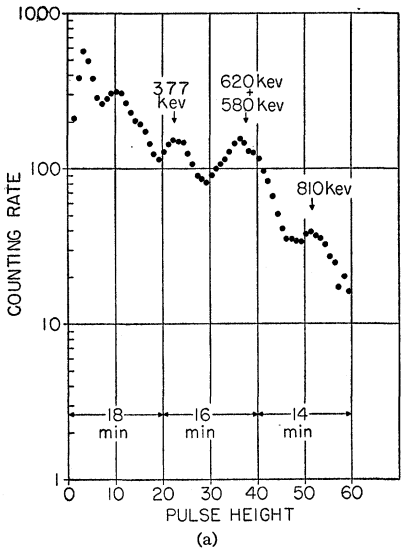
* Present address: Department of Nuclear Engineering, The Texas Agricultural and Mechanical College, College Station, Texas.

[1] C. L. McGinnis, Phys. Rev. **87**, 202(A) (1952).

[2] C. L. McGinnis (private communication, 1957) quoted in *Nuclear Data Sheets* (National Academy of Sciences, National Research Council, 1958).

[3] Robert G. Cochran and William W. Pratt, Phys. Rev. **109**, 878 (1958); **113**, 852 (1959).

[4] The separated isotope was obtained from the Oak Ridge National Laboratory.



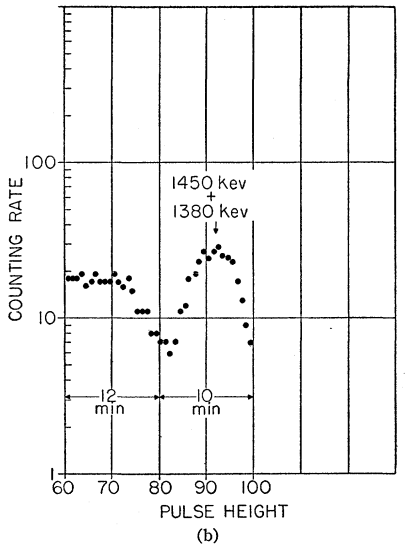
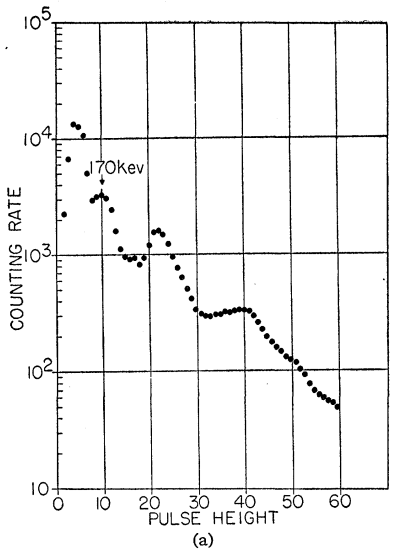


FIG. 3. Gamma-ray spectrum. Times indicated on the figures represent the starting time, measured from the end of exposure, of the one-minute interval during which the counting rate was observed.



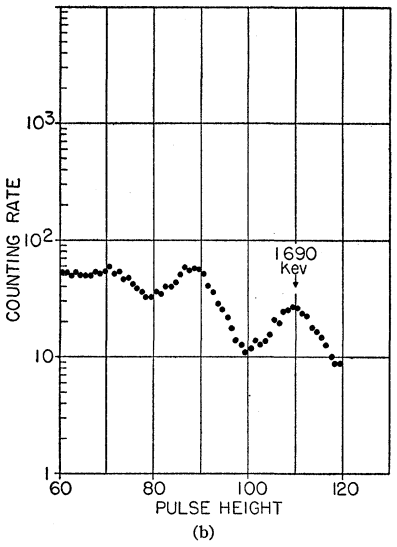


FIG. 4. Gamma-ray spectrum observed 10 hours after exposure.

from 0.56 to 2.02 Mev. The low-energy part of the spectrum (up to about 1 Mev) exhibits a long-lived component which is attributable to the 13.6-hour isomer of Pd^{109}. The high-energy part of the spectrum is attributed to the 5.5-hour isomer of Pd^{111}. The end point of the spectrum obtained from a Fermi plot is 2.02±0.10 Mev.

The gamma-ray spectrum observed from 10 to 18 minutes after a 20-minute exposure is shown in Fig. 3. The peaks whose energies are indicated in the figure are all found to decay with a half-life close to 22 minutes and are attributed to the Pd^{111} isomer with this half-life. The gamma-ray spectrum observed 10 hours after a 110-minute exposure is shown in Fig. 4. The peaks at 170 and 1690 kev are found to decay with a half-life close to 5.5 hours, and are attributed to the 5.5-hour isomer of Pd^{111}. All unlabeled peaks in Figs. 3 and 4 are assigned to contaminants in the source.

TABLE I. Beta and gamma rays in Pd^{111}.

ϵ_γ (Mev)	Relative intensity
22-minute isomer, ϵ_β=2.18±0.10 Mev	
0.377±0.005	5
0.580±0.010	13
0.620±0.010	
0.810±0.015	1
1.380±0.020	8
1.450±0.020	
5.5-hour isomer, ϵ_β=2.02±0.10 Mev	
0.170±0.010	7
1.690±0.030	1

The beta- and gamma-ray energies and relative intensities are listed in Table I.

Since it is known that an appreciable fraction of the decay of the 5.5-hour state goes by way of the 170-kev isomeric transition to the 22-minute state,[2] it is likely that the beta rays we have observed from the 5.5-hour state in reality represent the decay of the 22-minute state. The lack of similarity between the gamma-ray spectra associated with the two isomers, however, implies some degree of beta-ray branching directly from the 5.5-hour state.

PHYSICAL REVIEW VOLUME 118, NUMBER 5 JUNE 1, 1960

Beta Decay of Y^{91}†

O. E. JOHNSON AND W. G. SMITH
Physics Department, Purdue University, Lafayette, Indiana
(Received January 11, 1960)

The decay of Y^{91} was studied using NaI(Tl) scintillation counters and a 4π beta-ray scintillation spectrometer. A single gamma ray with a measured energy of 1.208±0.010 Mev was observed. The shape and end-point energy of the weak (~0.3%) beta group in coincidence with the 1.208-Mev gamma ray was measured. The end-point energy was determined to be 0.319±0.010 Mev. The experimental shape factor is clearly in disagreement with that predicted for a once-forbidden unique transition, $\Delta I=2$ (yes). The 0.319-Mev beta spectrum yields a shape factor which may, within experimental accuracy, be interpreted as a statistical shape. These measurements yield a Y^{91}-Zr^{91} mass difference of 1.527±0.014 Mev.

INTRODUCTION

THE decay schemes for Y^{91}, $t_{\frac{1}{2}}\sim 60$ days, as proposed in recent compilations of nuclear data[1,2] are in good agreement in so far as the major features are concerned. In Fig. 1, for reference purposes only, is given the decay scheme and "accepted" data as proposed by Way et al.[2] The ground-state beta group has been identified as a once-forbidden unique transition, $\Delta I=2$ (yes),[3] and the ground-state spin of Zr^{91} has been measured to be $\frac{5}{2}$.[4] Taken together, this information requires a spin of $\frac{1}{2}$ for the ground state of Y^{91} with parity opposite to that of the Zr^{91} ground state. The assignments of even parity for the ground state of Zr^{91} and odd parity for the ground state of Y^{91} are consistent with shell model predictions. Further, the even parity assignment for the ground state of Zr^{91} is supported by the measured magnetic moment of −1.3 nuclear magnetons[5] when compared with the Schmidt limits. The weak (~0.3%) beta transition ($E_{max}\sim 0.33$ Mev) populating a 1.22-Mev excited state of Zr^{91} as well as the 1.22-Mev gamma transition to the ground state was first reported by Bunker, Mize, and Starner[6] and later reported by Kahn and Lyon.[7]

The proposed decay scheme of Bunker et al.[6] includes an assignment of $\frac{5}{2}+$ for the 1.22-Mev state of Zr^{91}. These investigators point out that the logft value is somewhat large for a once-forbidden transition of the type $\Delta I=0$, 1 (yes). They also call attention to the possible unusual character of this state since the reaction $Zr^{90}(d,p)Zr^{91}$ seems to give no evidence for a level in Zr^{91} at 1.22 Mev.[8] This implies that the beta group populating the 1.22-Mev state would be a once-forbidden unique transition, $\Delta I=2$ (yes). However, Bunker et al., having measured this beta group, state that the poor resolution of the scintillation spectrometer used does not allow a conclusion as to whether the shape is statistical or of the once-forbidden unique type. On the other hand, the spin and parity assignment for this state proposed by Way et al.,[2] presumably based on the low values of the corrected comparative half-lives of the electron decay of Y^{91} and the electron capture transition of Nb^{91} to the 1.22-Mev state, is $\frac{1}{2}+$ or $\frac{3}{2}+$.

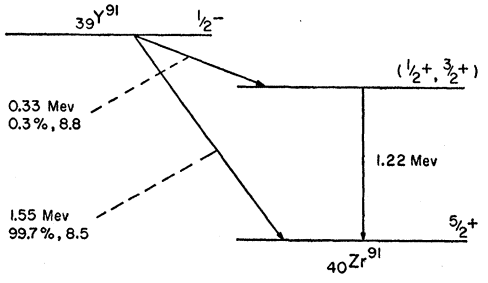


FIG. 1. The decay scheme of Y^{91} as proposed by Way et al., see reference 2, based on compiled nuclear data.

† Work supported in part by the U. S. Atomic Energy Commission.

[1] D. Strominger, J. M. Hollander, and G. T. Seaborg, Revs. Modern Phys. **30**, 585 (1958).

[2] *Nuclear Level Schemes*, $A=40-A=92$, compiled by K. Way, R. W. King, C. L. McGinnis, and R. van Lieshout, Atomic Energy Commission Report TID-5300 (U. S. Government Printing Office, Washington, D. C., 1955).

[3] L. M. Langer and H. C. Price, Jr., Phys. Rev. **76**, 186 (1949).

[4] O. H. Arroe and J. E. Mack, Phys. Rev. **76**, 873 (1949).

[5] S. Suwa, J. Phys. Soc. Japan **8**, 734 (1955).

[6] M. E. Bunker, J. P. Mize, and J. W. Starner, Phys. Rev. **94**, 1694 (1954).

[7] B. Kahn and W. S. Lyon, Phys. Rev. **98**, 58 (1955).

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