Decay Scheme of Pt^{199}†

J. M. LeBlanc, J. M. Cork,* and S. B. Burson
Argonne National Laboratory, Lemont, Illinois
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The radiations of the 30-min activity of Pt^{199} have been investigated with 180° magnetic photographic spectrometers and a 10-channel coincidence scintillation spectrometer. This activity of platinum has been found to decay by the emission of four beta rays with maximum energies of 0.8, 1.1, 1.3, and 1.7 Mev. Gamma rays with energies of 0.074, 0.197, 0.246, 0.318, 0.475, 0.54, 0.71, 0.79, and 0.96 Mev were detected. Extensive beta-gamma and gamma-gamma coincidence measurements were made; and an energy level scheme is proposed which is consistent with the results of all of the experiments.

A THIRTY-MINUTE activity which is produced by neutron capture in platinum was first reported in 1935.[1,2] McMillan *et al.*[3] assigned this activity to Pt^{199}. In 1941, Krishman and Nahum[4] studied the radiations emitted in the decay of Pt^{199} and established, by means of aluminum absorption experiments, that beta rays with a maximum energy of 1.8 Mev are emitted.

Sources of Pt^{199} were obtained in the present investigation by neutron irradiation of normal PtO. Seven internal conversion electron lines were detected with 180° spectrographs and are listed in Table I. The interpretation of these lines are listed in column 2 of Table I, and the gamma-ray energies are listed in columns 3, 4, and 5. The lines at 124, 144, 155, and 190 kev are identified by their energies as internal conversion electron lines in Hg, due to gamma rays emitted in the decay of Au^{199}, the daughter product of Pt^{199}. The 268- and 332-kev electron lines have the $K-L$ energy difference of Pt and are assigned to the 80-min activity of Pt^{197m} which has been reported[5] to decay by the emission of a 337-kev gamma ray. The energy of this transition as determined in the present study is 346 kev. The remaining three electron lines are interpreted as K internal conversion electron lines of gamma rays emitted in the decay of Pt^{199}.

Table I. Energies and interpretations of the observed internal conversion electron lines.

Electron line energy in kev	Interpretation	Gamma-ray energies Pt	Au	Hg
116	Au K		197	
124	Hg K			208
144	Hg L			159
155	Hg M			159
165	Au K		246	
190	Hg L			208
235	Au K		316	
268	Pt K	346		
332	Pt L	346		

The photon spectra of the 30-min platinum activity was studied with a 10-channel coincidence scintillation spectrometer.[6]

The NaI(Tl) pulse-height distribution from the gamma-rays of a PtO source which was irradiated for about 15 minutes is shown as the top curve in Fig. 1. Because of the short irradiation times, the activities of Au^{199} and Pt^{197} were not observed in these sources. The various peaks in the distribution are interpreted as indicating the presence of nine gamma rays with energies of 0.074, 0.197, 0.246, 0.318, 0.475, 0.540, 0.715, 0.790, and 0.96 Mev. All of these peaks were observed to decay with a half-life of 30±3 min and are, therefore, assigned to Pt^{199}.

The peak at about 70 kev in the pulse-height distribution occurs at an energy rather close to that of the K x-rays of gold (67 kev). One might conclude that it is due entirely to the gold x-rays. The energy of the peak is, however, slightly higher than the x-ray energy. In order to determine if this is an energy shift due to the presence of a gamma ray of about this energy, the scintillation spectrometer was set so that the ten channels just covered this peak. Then, without changing the spectrometer, the pulse-height distributions due to Tl x-rays (71 kev), the Pt^{199} peak, and the Pt^{199} peak in coincidence with the 246-kev gamma rays, were re-

Table II. Gamma-gamma coincidences observed in Pt^{199}. Where coincidences were observed between two gamma rays, an X is placed at the intersection of the corresponding row and column. The symbol 0 is used for gamma rays which are not in coincidence and blank spaces indicate cases where no data are available.

Gamma rays (energies in kev) \ Gamma rays (energies in kev)	960	790	715	530	475	318	246	197	74
74		0	X	0	X	0	X	X	
197				X	X	X	X		X
246				0	X	0	0	X	X
318		0	0	0	X	0	0	X	0
475		0	0	0	0	X	X	X	X
530		0	0	0	0	0	0	X	0
715				0	0	0			X
790				0	0	0			0
960									

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* University of Michigan, Ann Arbor, Michigan.
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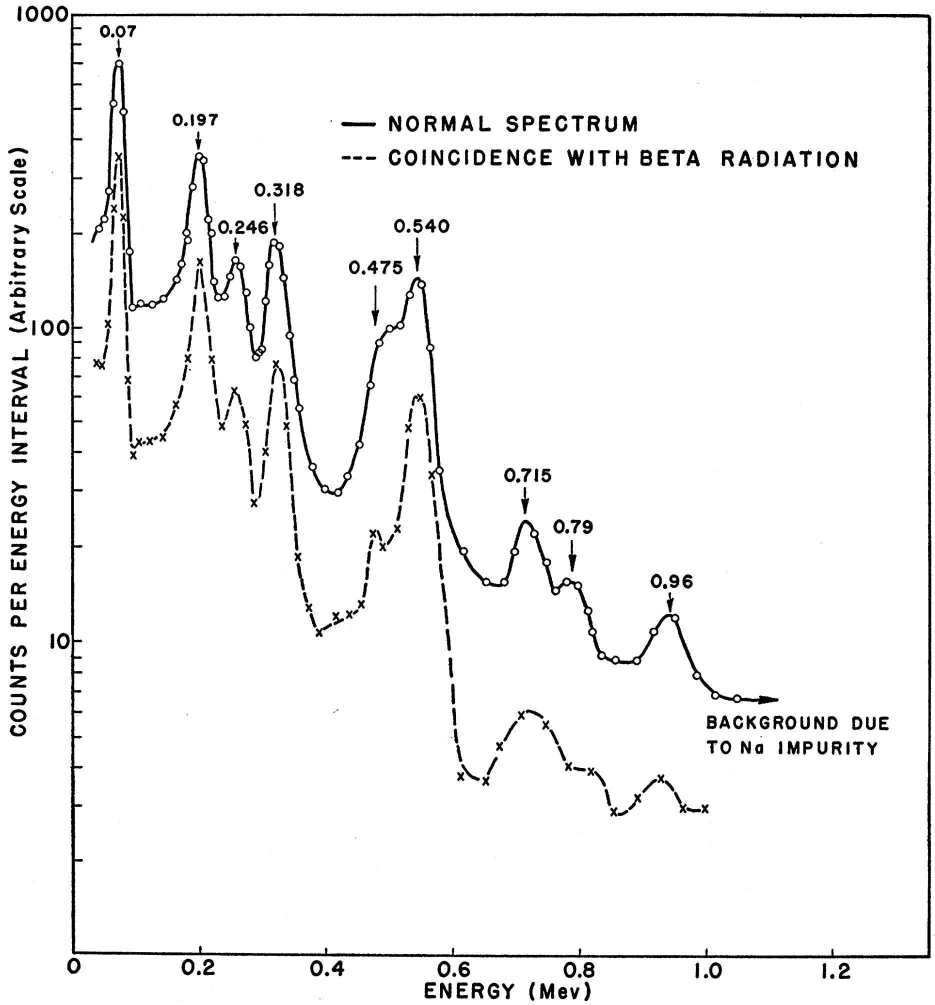

FIG. 1. The NaI pulse-height distribution of the gamma rays of $_{78}Pt^{199}$ (30 min).

corded. The results are illustrated in Fig. 2. It can be seen that the Pt^{199} peak in the normal distribution occurs at almost exactly the same energy as the Tl x-ray. This energy is 3 kev too high for the peak to be due entirely to Au x-rays. The fact that the Pt^{199} 70-kev peak is complex is clearly illustrated by the coincidence distribution (the dashed curve). The structure of this peak indicates the presence of a gamma ray at 74 kev. In addition, the small hump on the low-energy side of this peak occurs at about the energy of the Au x-ray. Thus, one concludes that a 74-kev gamma ray is emitted in the decay of Pt^{199}, and that the 70-kev peak in the normal distribution is a combination of this gamma ray and Au x-rays.

The pulse-height distribution of the gamma rays which are in coincidence with beta rays was measured and is shown as the dashed curve in Fig. 1. The 0.48, 0.71, 0.79, and 0.96 Mev gamma rays are not so strongly in coincidence with the beta rays as the other gamma rays. One explanation of this would be that these four gamma rays are transitions from a level which has a half-life which is comparable to the resolving time of the coincidence circuit, i.e., about 2 μsec.

By using an anthracene crystal for a beta-ray detector and measuring the attenuation in Al of the beta rays which are in coincidence with the various gamma rays, it was established that the 0.197- and 0.54-Mev gamma rays follow a beta ray which has a maximum energy of 1.1 ± 0.1 Mev. Similarly, it was established that the 0.246- and 0.318-Mev gamma rays follow a 1.3 ± 0.1-Mev beta ray, and the 0.71-, 0.79-, and 0.96-Mev gamma rays follow an 0.8 ± 0.1-Mev beta ray. A beta ray with a maximum energy of about 1.7 ± 0.2-Mev was detected in the singles aluminum absorption experiment, but was not observed to be in coincidence with any gamma rays. It is interpreted as a beta transition to the ground state of Au^{199}.

Extensive gamma-gamma coincidence measurements were made, and the results are summarized in Table II. The gamma rays are listed in the first row and column. Where coincidences are observed between two gamma rays, an X is placed at the intersection of the appro-

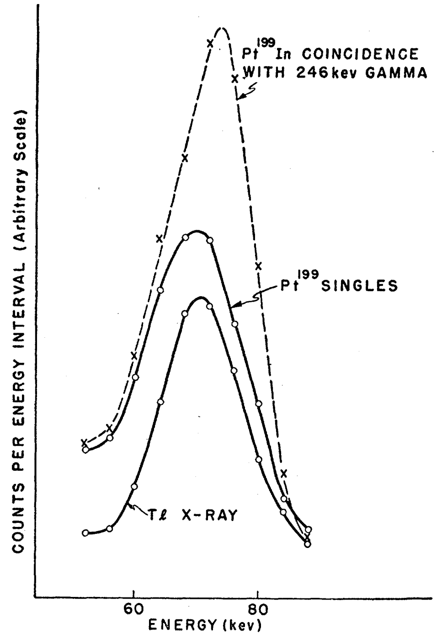

FIG. 2. NaI pulse-height distributions of the 70-kev peak.

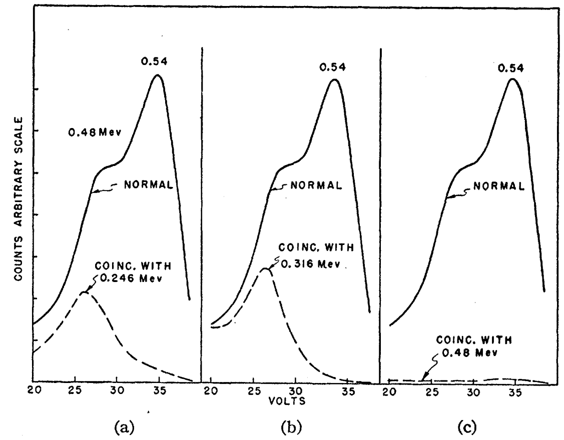

FIG. 4. Gamma-gamma coincidences in the 0.48- to 0.54-Mev region.

priate row and column. Gamma rays which are not in coincidence are indicated by an 0, and the spaces are blank where no data are available.

Strong coincidences were observed between the 74-kev transition and several other gamma rays. The NaI pulse-height distribution of the gamma rays which are in coincidence with the 74-kev transition is shown as the dashed curve in Fig. 3. From this distribution, one can conclude that the 74-kev transition is in coincidence with 197-, 246-, 475-, and 715-kev gamma rays, and not in coincidence with the 318-, 540-, and 790-kev gamma rays. The small coincidence peaks at 318- and 540-kev are interpreted as due to coincidences with the x-rays resulting from the internal conversion of the 197-kev gamma ray. One striking feature of the coincidence distribution is the intensity of the 246-kev peak relative to the intensity of the 197-kev peak. If one assumes that a small portion of the 246-kev coincidence peak is due to coincidences with x-rays, then one can conclude that the 74-kev transition is in coincidence with approximately equal amounts of the 197-kev and the 246-kev gamma rays. Since the 197-kev photopeak in the normal distribution is considerably stronger than the 246-kev photopeak, the 197-kev transition must be in coincidence with more than just the 74-kev and the 246-kev transitions.

If one examines the pulse-height distribution of gamma rays which are in coincidence with the 197-kev photopeak, one finds that it is in coincidence with the

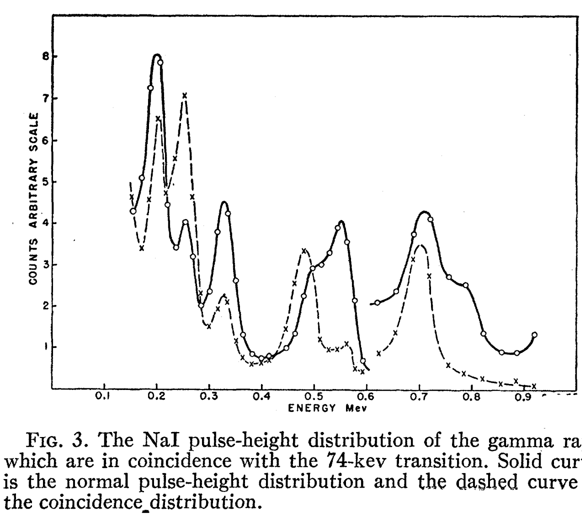

FIG. 3. The NaI pulse-height distribution of the gamma rays which are in coincidence with the 74-kev transition. Solid curve is the normal pulse-height distribution and the dashed curve is the coincidence distribution.

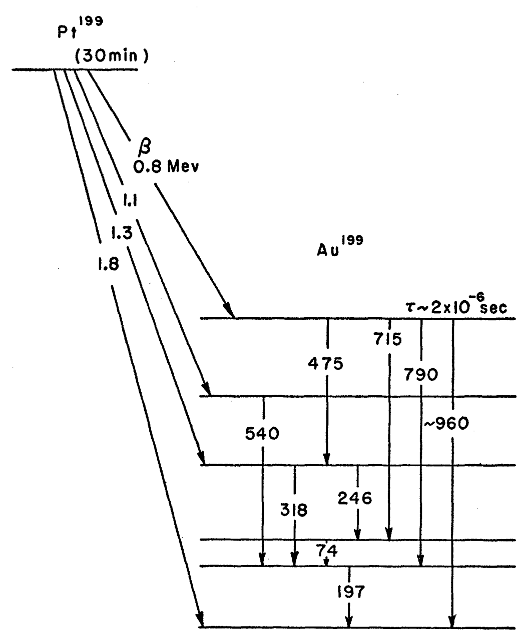

FIG. 5. The proposed decay scheme of ${}_{78}Pt^{199}$.

246-, 318-, 475-, and 540-kev transitions. The counting rates were not high enough to determine if the gamma rays with energies above 700 kev are also in coincidence with this transition.

The 0.48–0.54 Mev region of the pulse-height distribution is shown in Fig. 4. The normal pulse-height distribution is plotted in each part of the figure as a solid curve, and the distributions from gamma rays which are in coincidence with the 246-, 318-, and 475-kev photopeaks are plotted as dashed curves in (a), (b), and (c), respectively. From these curves one can conclude that the 475-kev gamma ray is in coincidence with both the 246- and 318-kev transitions, and that the 540-kev gamma ray is not in coincidence with the 246-, 318- or the 475-kev transitions. In a similar manner, it was established that the 246- and 318-kev radiations are not in coincidence with one another.

The proposed decay scheme for Pt^{199} is shown in Fig. 5. This scheme includes all of the beta rays and gamma rays which were detected in this study. The arrangement of the transitions is consistent with all of the coincidence measurements.

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Alpha-Alpha Particle Scattering in the Energy Range 12.3 to 22.9 Mev*†

R. NILSON,‡ R. O. KERMAN,§ G. R. BRIGGS,|| AND W. JENTSCHKE¶
Physics Department, University of Illinois, Urbana, Illinois
(Received September 10, 1956)

Absolute differential cross sections for alpha-alpha particle scattering have been measured at ten energies between 12.3 and 22.9 Mev. The laboratory angular range studied is 11° to 50°. The higher energy experiments at 21.65 to 22.9 Mev were concurrently carried out at two separate scattering chambers, one using nuclear emulsions as the detectors, the other, proportional counters. The experimental accuracy of these experiments is two percent or better at most angles. At the lower energies, 12.3 to 20.4 Mev, the study was made with nuclear emulsion detection only and the experimental accuracy is about three percent at most angles.

I. INTRODUCTION

THE verification[1] of Mott's theory of scattering of identical particles[2] plus the experimental demonstration of nuclear forces other than inverse square law forces[3,4] are two early credits to the study of alpha-alpha particle scattering. Recently, however, the continuing interest in the energy level spectrum of Be^8 has focussed attention again on the interactions possible between two colliding alpha particles.

Wheeler, in 1941,[5] was the first to consider the usefulness of analyzing the scattering results in terms of excited levels in Be^8. Although, on the basis of the variation with energy of partial wave phase shifts, Wheeler assigned spin and parity 0^+ to the now well-known 2.9-Mev 2^+ level, his method of phase analysis is sound and the incorrect assignment was probably due to inaccuracies in the early data.

The experiments on alpha-alpha particle scattering now encompass most of the range of bombarding energies between 0.4 and 30 Mev.[6–11] This paper discusses the experimental results of three separate and independent groups of scattering experiments which have been completed at the University of Illinois during the four years, 1951 to 1955. Preliminary reports[10] have been given on the first two groups of experiments which were performed with incident alpha particles of energies between 21.65 and 22.9 Mev. These experiments were performed concurrently with both photographic and proportional counter detection methods. The third and latest groups of experiments (photographic detection only, 12.3 to 20.4 Mev) parallels the work of Steigert and Sampson.[8]

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‡ Now at Hanford Atomic Products Operation, Richland, Washington.
|| Now at R.C.A., Princeton, New Jersey.
§ Now at Kalamazoo College, Kalamazoo, Michigan.
¶ Now at University of Hamburg, Hamburg, Germany.

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