PHYSICAL REVIEW VOLUME 95, NUMBER 1 JULY 1, 1954

Further Study of the Decay Scheme of Ir^{192}

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(Received March 15, 1954)

Scintillation spectrometer studies have revealed four high-energy gamma-ray components at 788, 883, 1080, and 1210 kev, with the possibility of a fifth component near 920 kev. The $Ir^{192}-Pt^{192}$ ground-ground state transition energy has been measured as 1490±20 kev. Level schemes are proposed for Pt^{192} and Os^{192}, the product nuclei upon the beta decay of Ir^{192}.

Decay schemes for the disintegration of Ir^{192} have been proposed on the basis of several earlier investigations.[1–3] In the present work the gamma-ray spectrum has been studied carefully in the high-energy region,[3] and new measurements have been made. The spectrum was obtained with a scintillation spectrometer of improved resolution, utilizing a $1\frac{1}{2}$ in.$\times 1\frac{1}{2}$ in. NaI(Tl) cylinder, DuMont K 1186 photomultiplier, and sliding channel differential discriminator. The resolution of the device was 7 percent for the 662-kev gamma ray from Cs^{137}.

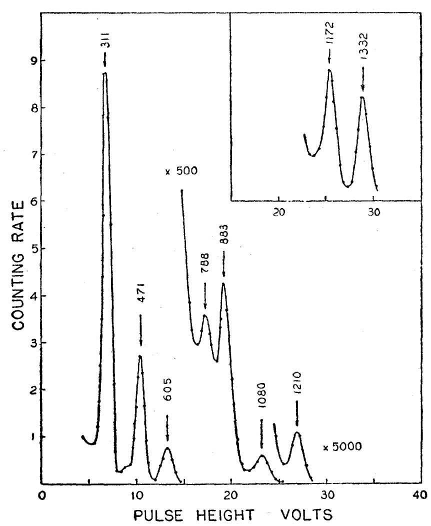

Fig. 1. Scintillation spectrometer pulse-height distribution for the gamma rays from Ir^{192}, showing four new high-energy components at 788, 883, 1080, and 1210 kev. An additional component at approximately 920 kev is inferred from a study of pulse-height distribution photographs, but is not resolved here. The inset shows the 1172- and 1332-kev lines from Co^{60}, used for calibration.

Figure 1 is the pulse-height distribution obtained with Ir^{192}, and the inset shows the 1172- and 1332-kev lines for Co^{60}, used for calibration of the high-energy components. The measurements were made with the source and detector in a 3-inch lead castle to reduce background. The feature at 311 kev is due to three unresolved gamma rays at 296, 308, and 316 kev (see Table I); the peak at 471 kev is the sum of the 468- and 485-kev lines with an intimation of the 415-kev line in the trough between 311 kev and 471 kev. At 605 kev is a peak due to two unresolved gamma rays at 605 and 613 kev. These energies were obtained using the 662-kev gamma ray from Cs^{137} for calibration. The high-energy radiation is of very low intensity as may be seen from the change in counting rate scale by a factor of 500 in Fig. 1, followed by a change to a factor of 5000. Four high-energy components are well resolved at 788 (0.9), 883 (1.9), 1080 (0.4), and 1210 (0.07) kev. Corrected gamma-ray intensities are given in parenthesis, and indicate percentage of the intensity of the unresolved group formed by the 605- and 613-kev gamma rays. An analysis of a number of long-exposure oscillograms of the pulse-height spectrum verified the presence of the four well-resolved components, and encouraged the belief that a further weak component existed close to 920 kev.

Table I. Comparative list of gamma rays from Ir^{192}. Energies in kev.

Cork	Muller	Roulston and Pringle	Present investigation	Energies used for level scheme
135.9	136.331			136
150				
173				173
201.1	201.306			201 *K*
205.7	205.376			205 *K*
283				283(*K*)
294.9	295.949			296
307.7	308.454			308
316.1	316.462			316
396				396 *K*
415.1				415
438				
467.4	467.984			468
484	484.75			485 *K*
588.6	588.40			588
603.7	604.53			605
611.2	612.87			613
		775	788	788
		870	883	883
		further un-	*ca* 920	921
		resolved radia-	1080	1080 *K*
		tions up to 1200	1210	1210

In order to be sure that these high-energy components were due to true cross-over transitions (see Fig. 2), and not due to "pileup," i.e., to chance coincidences

[1] Cork, LeBlanc, Stoddard, Childs, Branyan, and Martin, Phys. Rev. **82**, 258 (1951).
[2] Muller, Hoyt, Klein, and DuMond, Phys. Rev. **88**, 775 (1952).
[3] K. I. Roulston and R. W. Pringle, Phys. Rev. **87**, 930 (1952).

in the phosphor between gamma rays of energies to provide these lines as sums, the source-crystal distance was increased threefold, and the distribution was obtained again. If the lines were genuine they would have been reduced in the same proportion, due to the reduction in solid angle. Any spurious lines would have been reduced in proportion to the (solid angle)^2 since the probability for the occurrence of such an event is the product of the probabilities for the occurrence of each constituent event and these are proportional to the solid angle subtended by the crystal at the source. Since all the features in Fig. 1 were reduced in the same proportion it was concluded that the high-energy lines were due to genuine cross-over transitions. The low-energy features of the gamma-ray spectrum were obtained in a short time, but the high-energy required very long counting times, up to several hours on each point, in order to insure adequate statistics. A slight long-term drift in the energy scale was detected during these observations, and it became necessary to monitor the energy scale after each count.

Table I is a comparative list of gamma rays from the work of Cork *et al.* (beta-ray spectrometer), Muller *et al.* (crystal diffraction spectrometer), Roulston and Pringle (scintillation spectrometer), and the present investigation. The last column gives the best energy values, to the nearest kev, as they have been selected for use in the level scheme of Fig. 2. The association of a gamma ray with the K-capture process to Os^{192} is designated by K. This is done on the basis of Cork's beta-spectrometer measurements, for all but the 1080-kev component (see below).

A measurement of the $Ir^{192}-Pt^{192}$ ground-ground state transition energy was made to clarify the decay scheme. This was accomplished by measuring the integral bias end point for the beta-ray plus gamma-ray distribution due to a fine powder source of Ir^{192} immersed in a liquid scintillator consisting of xylene with 0.1 g/l diphenyloxazole and 4.0 g/l terphenyl.[4] The end point thus obtained was compared with the beta-ray-gamma-ray end point for a Cs^{137} source, using the end point for the Co^{60} gamma-ray distribution to correlate the two sets of measurements. The result of this measurement gave 1.49 ± 0.02 Mev for the $Ir^{192}-Pt^{192}$ ground-ground state transition energy. This is lower than an earlier reported value,[3] where the measurement was taken under less favorable circumstances with an Ir^{192} source external to a sodium iodide crystal, before efficient liquid scintillators were available.

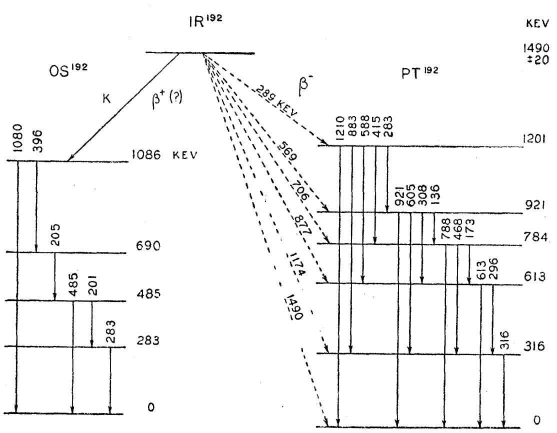

FIG. 2. Proposed level schemes for Pt^{192} and Os^{192}, following beta emission from Ir^{192}. The gamma-ray energies are the selected measured values (see Table I), the level values give the best fit to these, the $Ir^{192}-Pt^{192}$ ground-ground state transition energy is that obtained by direct measurement (see text), and the negatron partial components are those required to fit this transition energy and the proposed level scheme. There is evidence for the existence of five of these components (see reference 5).

The gamma rays listed in the last column of Table I made it possible to construct a decay scheme which was self-consistent and which made use of all but two of the gamma rays reported by Cork, without introducing any gamma rays that have not been observed directly either by Cork's group or in this laboratory. This scheme is shown in Fig. 2. The two unaccommodated gamma rays are the 150-kev line and the 438-kev line, which are both weak. Since the existence of these lines was based on single features of Cork's curves, their validity is doubtful. The ground-state transition from the level 921 kev in Pt^{192} is included in the scheme on the basis of the admittedly weak evidence mentioned above. It was not found possible to fit the 1080-kev gamma ray into the Pt^{192} level scheme, and its allocation to the Os^{192} scheme seems most plausible. In Fig. 1 the level values are chosen to give the best fit to the measured gamma-ray energies. The negatron partial components required to fit the Pt^{192} level scheme are indicated. A private communication from Kyles[5] indicates that whereas he has not observed the ground-ground state transition, he has evidence in support of the other five partial components of this scheme. The level scheme proposed for Pt^{192} is consistent with gamma-gamma[3] and beta-gamma[5] coincidence investigations. Gamma-gamma angular correlation studies will be undertaken to determine uniquely the spins of the excited levels of Pt^{192}.

To sum up, Ir^{192} decays by negatron emission to form Pt^{192} in five possible excited states, with no evidence for the ground-ground state transition; and by orbital electron capture to form Os^{192} in at least one excited state. While the possibility of positron emission cannot be ruled out, the absence of any features in the 511-kev region of the distribution, which would be the result of annihilation quanta, indicates that this mode of decay is very rare.

Our thanks are due to the National Research Council of Canada for the support of this work, and for the award of a Fellowship to one of us (H.W.T.).

[4] Pringle, Black, Funt, and Sobering, Phys. Rev. **92**, 1582 (1953).

[5] J. Kyles, University of Edinburgh (private communication).