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5.6-Second Ir^{191m} Following Os^{191} Decay*

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(Received October 15, 1954)

An isomeric transition in Ir^{191} has been found by direct isolation of the short-lived iridium activity from Os^{191}. This activity has previously been identified by Mihelich, McKeown, and Goldhaber by inelastic neutron excitation of iridium.[1] The osmium activity was prepared by a two-day neutron irradiation of natural osmium in the Brookhaven National Laboratory reactor.

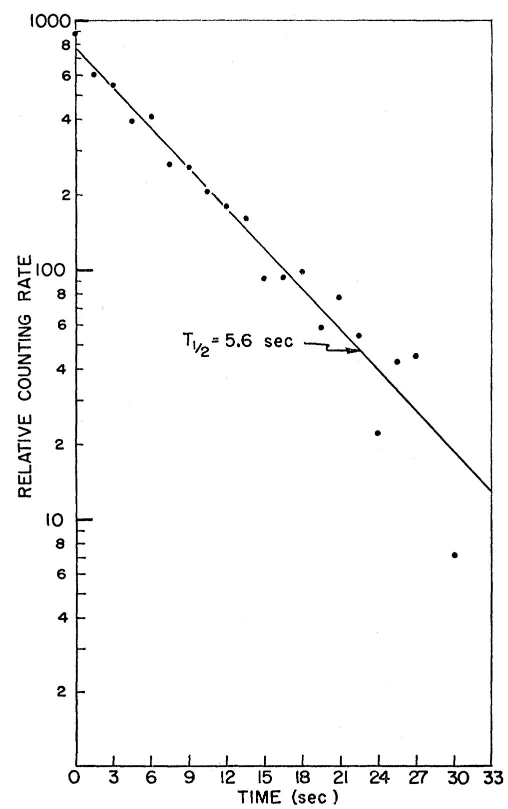

Fig. 1. Decay curve of Ir^{191m}.

After the 14-hour Os^{191m} and the 31-hour Os^{193} activities had decayed, the osmium target was converted to ammonium perosmiate, $(NH_4)_2OsO_5$, dissolved in dilute NH_4OH. To prepare the iridium activity, portions of this solution with added iridium carrier were dried on 1-mil platinum foils and then flamed over a Bunsen burner to drive off the osmium, leaving the iridium on the foil.

The Ir^{191m} sources were investigated with a NaI(Tl) scintillation spectrometer equipped for differential pulse height analysis. Positive identification of the activity as Ir^{191m} was made by observation of the 64-kev iridium x-ray and the 129-kev γ ray previously reported in the Pt^{191} decay,[2,3] and the Os^{191} decay.[4]

To determine the half-life of Ir^{191m} a constant-amplitude output signal from a differential discriminator set to accept pulses in the photopeak of either the iridium x-ray or the 129-kev γ ray was displayed on a 20-channel pulse height analyzer whose base line was varied at a uniform rate by a synchronous motor drive. In this manner the usual pulse height scale of the analyser was converted to a time scale, the channels registering counts occurring in consecutive 1.50-second periods. The half-lives obtained for the x-radiation and the 129-kev γ ray were identical. The average of several measurements, corrected for background, yielded a half-life for the Ir^{191m} activity of 5.6 ± 0.4 seconds. Figure 1 shows the decay curve obtained.

Os^{191} decays to an excited state of Ir^{191} which then emits γ rays of 129 and 42 kev.[5] On the basis of the conversion ratios $K:L_{I}:L_{II}:L_{III}$ the 129-kev transition has been identified as a mixed $M1+E2$ transition,[2] and consequently is expected to have a lifetime of the order of 10^{-10} seconds. Because the 129-kev transition in Ir^{191m} was observed to decay with a 5.6-second half-life, it must be concluded that the 129-kev γ ray follows the 42-kev γ ray, which experimentally confirms the level order previously surmised from the Pt^{191} data.[2]

Using Weisskopf's formulas for the lifetimes of radiative transitions[6] and the tables of conversion coefficients of Rose *et al.*,[7] the expected lifetimes of various 42-kev transitions in Ir^{191} have been calculated and are given in Table I. The entries in this table are the radiative

Table I. Calculated lifetimes of 42-kev transitions in Ir^{191} for various multipole orders.

Multipole order	Electric transition sec	Magnetic transition sec
1	2(−15)[a]	3(−11)
2	1(−5)	1(−7)
3	9(−1)	7(0)
4	5(5)	6(6)
5	4(14)	3(11)

[a] $a(b) \equiv a\times10^{b}$.

lifetime divided by the sum of conversion coefficients $1+\alpha_{LI}+\alpha_{LII}+\alpha_{LIII}$ (K-shell conversion is prevented by the low γ-ray energy). It is evident that the measured

lifetime is consistent only with the identification of the 42-kev transition as $E3$ or $M3$ since Weisskopf's formulas appear to be valid within a factor of 10^4. It is not possible to choose between $E3$ and $M3$ on the basis of the lifetime measured here.

* This work was supported by the U. S. Atomic Energy Commission and the Higgins Scientific Trust Fund.

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Multiple Photon Production in Electron-Positron Annihilation

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DUE to the small value of the fine structure constant, multiple processes in quantum electrodynamics have not received much attention. In fact, it is usually believed[1,2] that the cross section for a process involving multiple production of photons is always much smaller than the cross section for a similar process involving the production of a lesser number of photons.

In order to see whether the above belief is justified even at very high energies, we have investigated the multiple production of photons due to the annihilation of an electron-positron pair. It is found that in the extreme relativistic case the cross section for the production of three photons in the electron-positron annihilation is

$$\sigma_3=\alpha^3\frac{c^2\hbar^2}{\mu E}\left(\log\frac{2E}{\mu}\right)^3, \tag{1}$$

where α is the fine structure constant, μ is the rest energy of the electron or the positron, E is the energy of the incident positron, and we have assumed that the electron is at rest. Further, an estimate of the cross section for the production of n photons in the electron-positron annihilation shows that

$$\sigma_n\approx\pi^{3-n}\alpha^n\frac{c^2\hbar^2}{\mu E}\left(\log\frac{2E}{\mu}\right)^{2n-3}. \tag{2}$$

We can now compare the cross sections (1) and (2) with the cross section for the production of two photons in the electron-positron annihilation, which in the extreme relativistic case is given by[1]

$$\sigma_2=\pi\alpha^2\frac{c^2\hbar^2}{\mu E}\log\frac{2E}{\mu}. \tag{3}$$

It is then evident that σ_n is of the same order as σ_2 when

$$\frac{\alpha}{\pi}\left(\log\frac{2E}{\mu}\right)^2\approx 1. \tag{4}$$

Thus, in spite of the smallness of the fine structure constant, the role of multiple processes in quantum electrodynamics is not negligible at very high energies.

Recently Schein and co-workers[3] have observed a very unusual shower of about 20 photons, which are unaccompanied by charged particles and are contained in a very narrow cone. Due to the absence of charged particles in the photon shower, it seems that these photons were produced by the annihilation of a charged particle and its antiparticle. Moreover, in order to account for the narrow width of the photon shower, Schein[4] has estimated that the energy of the incident particle is about 10^8 times its rest energy. Now, when $E\approx 10^8\mu$, we find that $(\alpha/\pi)[\log(2E/\mu)]^2\approx 1$, and therefore in such a case multiple production of photons can easily take place. This shows that Schein's photon shower could have been produced by the annihilation of an electron-positron pair, the energy of the incident positron being about $10^8\mu$ or about 0.5×10^{14} ev.

It should be noted that it would be rather difficult to provide any other explanation for the event observed by Schein. For instance, in the annihilation of a proton-antiproton pair the probability for the production of π mesons far exceeds the probability for the production of photons,[5] and therefore the proton-antiproton annihilation can hardly give rise to a pure photon shower.

The present investigation also serves to show that more attention should be paid to the study of multiple photon production in various elementary processes in quantum electrodynamics. Multiple processes may provide us with a test of the validity of the present quantum electrodynamics at exceedingly high energies.

A detailed account of this work will be published shortly.

I would like to express my sincerest thanks to Professor K. Lark-Horovitz and Professor M. Schein for several interesting discussions.

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