excess of the quantum cross section over the SCT cross section is 0.1 percent of the whole. The numbers recorded in the table are not as accurate as the number of significant figures would suggest. The intended accuracy was about one percent but internal consistency indicates that it may be better. The second column minus the third when summed over different L contributes to the excess of $10^6 \sum \mathcal{C}_L$ over the SCT approximation the amounts -6.2, $+2.2$, -1.3, and -0.6 from the L ranges 0, 1–10, 11–50, 51—∞ respectively. The total difference is -5.9, about -1 percent of the total. At the end of the work a slight error was found in the quantum values for $L=20$, 30, 50. A crude correction replaces the -1.1, -1.1, -1.5 percent entries by roughly $+3$ percent to 1.7 percent, replacing the total quantum-classical difference by ~ 1.0, *i.e.*, ~ 0.2 percent of total. With either interpretation the difference is one percent or less of the total cross section.

* This research was supported by the Office of Ordnance Research, U. S. Army.

[1] T. Huus and Č. Zupančič, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **28**, No. 1 (1953).
[2] Biedenharn, Gluckstern, Hull, and Breit, Phys. Rev. (to be published).
[3] Bloch, Hull, Broyles, Bouricius, Freeman, and Breit, Phys. Rev. **80**, 553 (1950); B. E. Freeman, Dissertation, Yale University, 1950 (unpublished).

Spin, Magnetic Moment, and Hyperfine Structure of Rb^{81}*

J. P. Hobson,† J. C. Hubbs,‡ W. A. Nierenberg, and H. B. Silsbee

University of California, Berkeley, California

(Received October 11, 1954)

THE spin, hyperfine splitting, and nuclear moment of Rb^{81} (4.7 hr) have been measured. They are 3/2, 5000±125 Mc/sec, and 2.00±0.06 nuclear magnetons respectively. The zero-moment method of atomic beams was used. Figure 1 shows the zero-moment curve

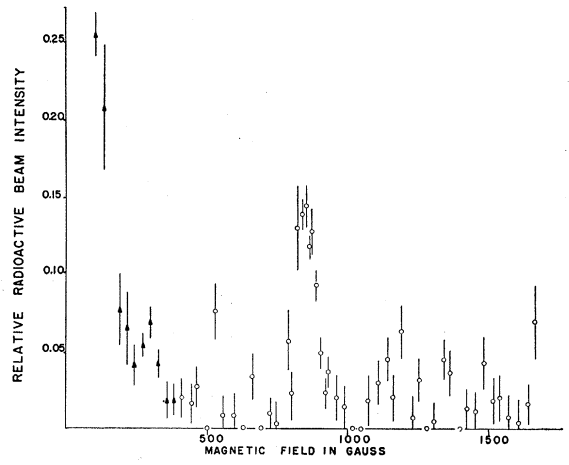

FIG. 1. Rb^{81} zero-moment curve.

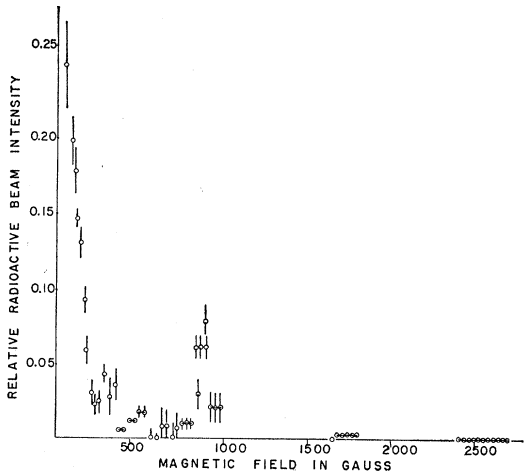

FIG. 2. Rb^{81} zero-moment pattern.

(beam intensity *vs* magnet current) for Rb^{81}. A peak appears at approximately 850 gauss. The run did not remove the possibility of spin 5/2 or 7/2. Figure 2 is another run which shows the 850-gauss peak but shows no peaks at 1700 or 2550 gauss, thus establishing the spin as 3/2. Calibration of the fields with natural Rb established the hyperfine splitting, and the ratio of radio-rubidium to natural rubidium hyperfine splittings determined the magnetic moment.

The detection was accomplished by collection of the neutral beam on sulfur buttons and counting the K x-rays. The sulfur surface collection was one of many methods tried and it apparently gave nearly full efficiency. The K x-rays were absorbed in a 1 mm×½ in. ×½ in. NaI(Tl) crystal which gave nearly 50 percent efficiency with a minimum counting background.

The isotope was produced by α bombardment and therefore had carrier added to optimize the beam. It was identified by the chemistry, its decay curve, and the behavior of the sample as a function of α energy.

There is a suggestion of a peak at 290 gauss in Fig. 1, possibly due to Rb^{82}. Further runs are being made to improve the statistics in this region and at multiples of this field.

* This research has been supported by the U. S. Office of Naval Research.
† Now at the National Research Council of Canada, Ottawa, Canada.
‡ Now at Columbia University, New York, New York.

$E3$ Isomer in Ir^{191}*

J. W. Mihelich,† M. McKeown, and M. Goldhaber

Brookhaven National Laboratory, Upton, New York

(Received October 15, 1954)

IT has been established[1] that Os^{191} (16 day) decays via a β transition to an excited level in Ir^{191}, followed by two γ-ray transitions in cascade (42 and 129 kev).

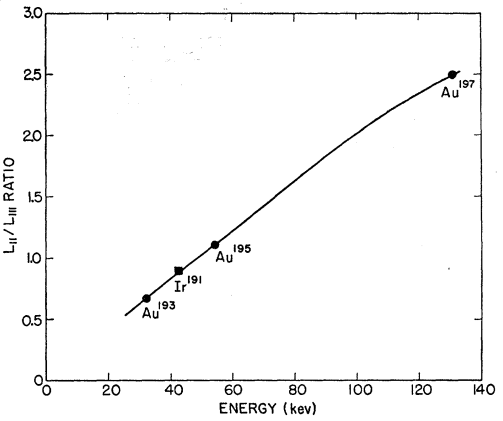

FIG. 1. Experimental L_{II}/L_{III} ratios for $E3$ transitions as a function of energy for transitions in elements of $Z=79$ and $Z=77$.

Kondaiah[2] had reported the existence of $\beta-\gamma$ coincidences. Since the L conversion pattern for the 42-kev transition ($L_I:L_{II}:L_{III}=<0.1:0.8:1.0$) indicated either an $E2$ or $E3$ transition, Swan and Hill[3] concluded that the multipolarity was $E2$. Since then, however, McGowan[4] has found that no $\beta-\gamma$ coincidences could be observed. Hence, the existence of an isomer of $\Delta I=3$ is indicated.

Accordingly, we have searched for a measurable half-life by irradiating separated Ir isotopes (shielded by boron) with fast pile neutrons and observing the decay rate of the 129-kev γ-ray. The technique used was that of Scharff-Goldhaber and McKeown[5] as employed in their search for isomers with half-lives of the order of seconds. We have found a photopeak of 129 kev connected with Ir^{191} and decaying with a half-life of 6.8 ± 1.0 sec. Naumann and Gerhart have subsequently obtained a more accurate value of this half-life ($T_{\frac{1}{2}}=5.6\pm0.4$ sec).[6] Hence, we must conclude that either the 42-kev transition or an as yet unobserved transition is responsible for the 5.6-sec half-life. It has been shown previously that the 129-kev γ-ray is in prompt coincidence with preceding γ-rays in the K-capture decay of Pt^{191}.[7]

It is of interest to note that Butement and Poe[8] have assigned a 7.3-second isomer to Ir^{194m}, because they produced such an activity with fast neutrons on Ir and Pt. They observe a γ-ray of 125 kev (with an x_K/γ ratio of 1.5, as compared to the value of 2.0 for the 129-kev transition in Ir^{191}) and a γ-ray of 5.6 Mev, both decaying with the 7.3-second half-life. We should like to suggest tentatively that they were exciting the isomeric level in Ir^{191}, and that the 5.6-Mev peak may correspond to the 6.1-Mev transition (full energy less 0.51 Mev) in N^{16} (7.3 sec) produced by the $O^{16}(n,p)N^{16}$ reaction on oxygen present as an impurity in the Ir and Pt samples. We have, however, not pursued this point further.

In the series of $E3$ isomers[9] found in the odd-A isotopes of Au, L ratios were obtained for several transition energies. Figure 1 is a plot of these ratios ($Z=79$) as a function of energy. The point for Ir($Z=77$) is indicated. Hence, on the basis of these empirical data it is not unreasonable to assume that the 42-kev transition in Ir^{191} be of $E3$ character.

TABLE I. Dependence of L_{II}/L_{III} ratio on Z.

Z	Energy kev	L_{II}/L_{III}	Ref.
85	100	2.9	a
79	100	1.9	b
66	109	1.4	c
47	93	1.1	d

[a] From tables of reference 10.
[b] Interpolated value from data on Au isomers. See reference 9.
[c] Jordan, Cork, and Burson, Phys. Rev. **91**, 497 (1953).
[d] F. A. Johnson, Can. J. Phys. **31**, 1136 (1953).

The tables of Rose, Goertzel, and Swift[10] do not, so far, include values of L_{III} conversion coefficients for atomic numbers other than $Z=85$. For this atomic number and an $E3$ transition of 42 kev, the value of L_{II}/L_{III} would be 2.34. The measured value for Ir^{191} is ~0.8.[3,11] However, apparently this ratio is a rapidly varying function of Z between $79\leq Z\leq85$. This is shown in Table I which lists L_{II}/L_{III} ratios for several $E3$ transitions of approximately 100 kev and various values of the atomic number.

Ir^{191} has a ground state characterized by the assignment $d_{3/2}$.[12] Since the successively higher levels are depopulated by $M1+E2$[13] and $E3$ transitions, respectively, the indicated level assignment for the excited states on the unified model[14] are $d_{5/2}$ and $h_{11/2}$, in strong analogy with the odd-A isomers of Au.[9] Figure 2

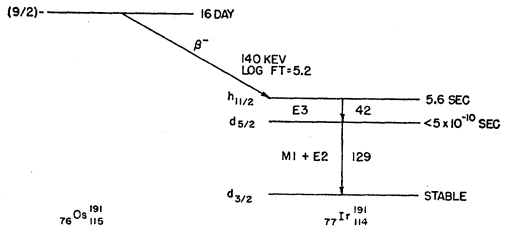

FIG. 2. Levels of Ir^{191} populated by β decay of Os^{191}.

presents a decay scheme which is consistent with the experimental data and with theoretical expectations.

The separated Ir isotopes were obtained from the Stable Isotope Division, Oak Ridge.

* Under the auspices of the U. S. Atomic Energy Commission.
† Now at University of Notre Dame, Notre Dame, Indiana.
[1] *Nuclear Data*, National Bureau of Standards Circular No. 400 (U. S. Government Printing Office, Washington, D. C., 1950); Hollander, Perlman, and Seaborg, Revs. Modern Phys. **25**, 469 (1953).
[2] E. Kondaiah, Arkiv Fysik **3**, 47 (1951).
[3] J. B. Swan and R. D. Hill, Phys. Rev. **88**, 831 (1952).
[4] F. K. McGowan, Phys. Rev. **93**, 163 (1954).
[5] G. Scharff-Goldhaber and M. McKeown, Phys. Rev. **95**, 613(A) (1954).
[6] R. A. Naumann and J. B. Gerhart, following letter [Phys. Rev. **96**, 1452 (1954)].
[7] Tomlinson, Naumann, and Mihelich, Phys. Rev. **94**, 794 (1954).

[8] F. D. S. Butement and A. J. Poe, Phil. Mag. **45**, 31 (1954). [*Note added in proof.*—See also the subsequent communication by these authors, Phil. Mag. **45**, 1090 (1954).]
[9] Gillon, Krishnan, de Shalit, and Mihelich, Phys. Rev. **93**, 124 (1954).
[10] Rose, Goertzel, and Swift, "L-Shell Conversion Coefficients" (privately circulated).
[11] J. W. Mihelich, Phys. Rev. **87**, 646 (1952).
[12] Brix, Kopferman, and Siemans, Naturwiss. **37**, 397 (1950).
[13] An upper limit of 5×10^{-10} sec for the half-life of this transition has been found by A. W. Sunyar (private communication).
[14] M. G. Mayer, Phys. Rev. **78**, 16, 22 (1950); Haxel, Jensen, and Seuss, Z. Physik **128**, 301 (1950); A. Bohr and B. Mottelson, Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd., **27** (1953).

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

R. A. NAUMANN AND J. B. GERHART

Palmer Physical Laboratory, Princeton University, and Frick Chemical Laboratory, Princeton University, Princeton, New Jersey

(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.

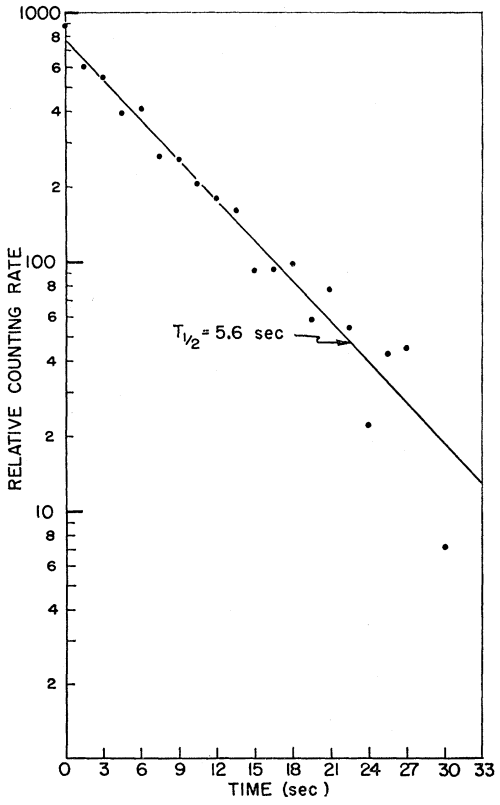

FIG. 1. Decay curve of Ir^{191m}.

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 $K:L_{\rm I}:L_{\rm II}:L_{\rm III}$ 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