Title
SPINS OF INDIUM-109, INDIUM-110m, AND INDIUM-111

Permalink
https://escholarship.org/uc/item/57c6n1mz

Authors
Marino, Lawrence L.
Ewbank, Wesley B.
Nierenberg, William A.
et al.

Publication Date
1958-02-24

UCRL-8187

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UCRL-8[illegible]

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

SPINS OF INDIUM-109, INDIUM-110m, AND INDIUM-111

Lawrence L. Marino, Wesley B. Ewbank, William A. Nierenberg,
Howard A. Shugart and Henry B. Silsbee

February 24, 1958

Printed for the U. S. Atomic Energy Commission

SPINS OF INDIUM-109, INDIUM-110m, AND INDIUM-111

Lawrence L. Marino, Wesley B. Ewbank, William A Nierenberg
Howard A. Shugart and Henry B. Silsbee
Radiation Laboratory and Department of Physics
University of California, Berkeley, California

February 24, 1958

ABSTRACT

The nuclear spins of three neutron-deficient radioactive isotopes of indium have been measured by the use of the atomic-beam magnetic-resonance technique. Results are $I = 9/2$ for 4.3-hr In^{109}; $I = 7$ for 5.0-hr In^{110m}; and $I = 9/2$ for 2.8-day In^{111}.

SPINS OF INDIUM-109, INDIUM-110m, AND INDIUM-111[*]

LawrenceeL. Marino, Wesley B. Ewbank, William A. Nierenberg,[†]
Howard A. Shugart, and Henry B. Silsbee
Radiation Laboratory and Department of Physics
University of California, Berkeley, California

February 24, 1958

EXPERIMENTAL METHOD

The atomic-beam magnetic-resonance flop-in technique using radioactive detection has been applied to the measurement of the spin angular momentum of three indium isotopes. The spin-measuring procedure, which involves observin $\Delta m_F = \pm 1$ transitions in the linear Zeeman region, has been given earlier.[1] Of the two electronic states ($^2P_{1/2}$ and $^2P_{3/2}$) that are populated at the temperature of the oven, the $^2P_{3/2}$ state gives larger resonances with our apparatus and was used for the measurements described here. In particular, Table I gives the transitions that have been observed for the various isotopes. A second oven containing rubidium bromide and calcium provided an easily detectable atomic beam of rubidium for field calibration.

TABLE I

Isotope	Electronic State	F	m_F
109	$^2P_{3/2}$	6	$-4 \leftrightarrow -5$
		5	$-3 \leftrightarrow -4$
110m	$^2P_{3/2}$	17/2	$-13/2 \leftrightarrow -15/2$
111	$^2P_{3/2}$	6	$-4 \leftrightarrow -5$

---

[*] Research supported jointly by the U. S. Atomic Energy Commission and the Office of Naval Research.

[†] Professor in the Miller Institute for Basic Research in Science.

The isotopes In^{109} (4.3 hr),[2] In^{110m} (5.0 hr),[3] and In^{111} (2.8 day)[3] were made in the Crocker 60-in. cyclotron on the Berkeley campus, using (α, kn) reactions in 0.010-in. silver foil. Following solution of the silver foil in concentrated nitric acid with about 10 mg of indium carrier, the silver was precipitated as the chloride by the addition of concentrated HCl. After the precipitate was separated by centrifuging, oxalic acid or Rochelle salt was added to the supernatant for plating purposes. From a slightly acid solution the indium was then electroplated onto either a platinum or indium electrode, using 0.2 amp plating current. At first the electrode was placed directly in either a carbon or a tantalum oven, which was heated in the apparatus by electron bombardment. Later experimentation showed that a steadier beam resulted if the indium deposit was scraped from the platinum electrode. The chemical separation required about 1.5 hours.

INDIUM-111 RESULTS

Because runs 88 and 93 were made several days after the bombardments, the shorter-lived isotopes had decayed, leaving relatively pure In^{111}. With only a single activity present in the beam, resonance indications must be determined on the basis of absolute counting rates. The results of spin searches are indicated in Table II. For runs 88 and 93 the spin-9/2 signals are an order of magnitude greater than those for other half-integral values. Decay curves for these resonances showed a single 2.8-day component which indicated that In^{111} was responsible for the signal. The In^{111} resonance has been observed from 4.8 to 7.8 Mc/sec. to establish the linear Zeeman dependence of the resonance frequencies on the low-transition magnetic field.

INDIUM-110m RESULTS

When the target was processed immediately after bombardment, it contained in addition to In^{111} several other isotopes including (4.3 hr) In^{109} and (5.0 hr) In^{110m}. Because of low counting rates it is not possible to distinguish between 4.3 and 5.0 hours by decay alone. However, In^{109} must have half-integral spin while In^{110m} must have integral spin. This information along with an approximate half-life determination suffices to establish the identity of these short-lived isotopes.

TABLE II

Table of initial counting rates of indium spin searches.*

Run	1	2	5/2	7/2	4	9/2	5	11/2	6	7	8
88 (In^{111} only)			0.5(1)	0.8(1)		5.2(2)					
93 (In^{111} only)				0.6(1)		6.6(2)		0.4(1)			
96	0.9(3)†	0.5(1)		0.8(1)	0.4(1)	2.3(2)	0.7(2)		0.4(1)	1.6(2)	
104						8.2(3)	1.9(2)			4.5(2)	3.5(2)§
107	a resonance sweep of In^{109} at 22 Mc/sec.										
108	a resonance sweep of In^{110m} at 12 Mc/sec.										

---

*These rates (in arbitrary units) are corrected for counter background and normalized for variations in beam intensity within a single run. All runs were performed at different values of magnetic field.

†Poor normalization

§The $^2P_{3/2}$, $F = 5$, $m_F = -3 \leftrightarrow -4$ transition for $I = 9/2$ occurs at the same frequency as the $^2P_{3/2}$, $F = 19/2$, $m_F = -15/2 \leftrightarrow -17/2$ transition for $I = 8$ within the line width.

Because three isotopes contribute to the initial counting rates, each sample may be analyzed for the relative composition of short (4.3-and 5.0-hr) activity and long (2.8-day) activity. When this is done as shown in Table III for run 104, the ratio of short to long components of the counting rate on the "half-beam" sample (magnets on but stop-wire removed) at zero time is 3.1. The spin-5 sample, though very small in absolute counting rate, shows a similar ratio (2.4) for an apparatus background sample, as would be expected. On the other hand, it is clear from Table III that the spin-7 sample contains an enhanced short component (In^{110m}). In fact the short component on the spin-7 sample is 2.7 times the apparatus background (spin-5 sample), while the long components are essentially equal. Further confirmation of spin 7 for In^{110m} comes from information of runs 96 and 108. In run 96 (Table II) the normalized counting rate for spin 7 is 3.7 times the average rate for the other integral spins. (In run 104 the signal at "spin 8" is the $^2P_{3/2}$, $F = 5$, $m_F = -3 \leftrightarrow -4$ transition for the 9/2 material. This signal supports the 9/2 assignment of In^{109} and In^{111}.)

TABLE III

Composition analysis of samples from run 104. Counting rates are not corrected for variations in beam intensity.

Sample	Short activity (cpm)	Long activitiy (cpm)	Ratio $\frac{\text{Short}}{\text{Long}}$
"Half-beam"	276 (3)	90 (2)	3.1(2)
9/2	9.9(7)	5.6 (4)	1.8 (2)
5	2.6(4)	1.1 (2)	2.4 (6)
7	7.1(1)	1.5 (2)	4.7 (8)

INDIUM-109 RESULTS

The spin-9/2 button of run 104 (Table III) shows significantly more short activity (9.9 cpm) than a typical background sample, e.g. spin 5 with only 2.6 cpm of short activity. The exposures were roughly equal; so the enhancement by a factor 3.8 is attributed to a spin-9/2 signal from In^{109}. Likewise the composition of the I = 9/2 sample differs from that of the "half-beam" sample in such a way as to indicate the relative enrichment of In^{109} and In^{111} over In^{110m}. The signal also has about the right magnitude, for if In^{109} and In^{110m} were produced more or less equally, the "half-beam" shows that each would contribute about 1.5 times as much initial activity as In^{111}. The observed ratio of In^{109} to In^{111} on the spin-9/2 sample is 1.8 before any apparatus background corrections. Similar results from other runs have confirmed the 9/2-spin assignment to In^{109}.

REMARKS

Spin 9/2 for In^{111} and In^{109} agrees with the simple shell-model prediction that the forty-ninth proton is in a $g_{9/2}$ state.[4] Spin 7 for In^{110m} could arise from coupling of a $g_{9/2}$ proton and a $d_{5/2}$ neutron, which is predicted by the shell model in this region. The series from In^{110m} (I = 7) to In^{114m} [5] and In^{116m} (I = 5)[5, 6] may then illustrate the transition from a $d_{5/2}$ to an $s_{1/2}$ level for the odd neutron.

REFERENCES

1. Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, Phys. Rev. 104 , 10[illegible] (1956).
2. E. C. Mallary and M. L. Pool, Phys. Rev. 76, 1454 (1949).
3. Carl L. McGinnis, Phys. Rev. 81, 734 (1951).
4. M. G. Mayer and J. H. D. Jensen, Elementary Theory of Nuclear Shell Structure (Wiley, New York, 1955) pp. 74-81.
5. L. S. Goodman and S. Wexler, Phys. Rev. 100, 1245 (1955); Phys. Rev. 100, 1796 (1955); and Phys. Rev. 108, 1524 (1957).
6. P. B. Nutter, Phil. Mag. 1, 587 (1956).

Information Division
br