The Nuclear Spin and Quadrupole Moment of I^{131}†

RALPH LIVINGSTON AND BEN M. BENJAMIN, *Oak Ridge National Laboratory, Oak Ridge, Tennessee*

AND

J. T. COX AND WALTER GORDY, *Department of Physics, Duke University, Durham, North Carolina*

(Received July 27, 1953)

Measurements on the $J=2\rightarrow3$ rotational transition of CH_3I^{131} have been made in the 6.75-mm wavelength region. The nuclear spin of I^{131} was found to be 7/2 and the quadrupole coupling, -973 ± 9 Mc/sec. This coupling gives -0.412×10^{-24} cm^2 for the quadrupole moment of I^{131}.

THE nuclear spin and quadrupole moment of radioactive, 8-day half-life I^{131} has been determined from measurements on the $J=2\rightarrow3$ rotational transition of CH_3I^{131} which occurs in the 6.75-mm wavelength region. I^{131} has a nuclear spin of 7/2 as evidenced by the closeness of the fit of the lines in Fig. 1. Calculated spectra for spin cases of 3/2, 5/2, and 9/2 could not be fit. Only the stronger lines were observed because of the small sample size, estimated to be approximately 2μg of I^{131} as CH_3I.

The quadrupole coupling was computed to be -973 ± 9 Mc/sec. Table I shows the closeness of the fit of the observed to calculated line frequencies using this coupling value. The value of D_{JK} for CH_3I^{127} was used in the calculations since it should be essentially unchanged for CH_3I^{131}. Second-order corrections were not calculated, but these are expected to be much smaller than for I^{127} or I^{129} in view of the smaller coupling. These corrections may, in part, account for the small differences between the observed and calculated frequencies of Table I.

The stronger lines of CH_3I^{129} present in the sample were also observed, and these were easily identified from previous accurate measurements. One pair of I^{129} lines did appear, however, at about the same frequency as I^{131} lines as indicated in Table I. The computed center of the CH_3I^{131} spectrum was shifted the expected amount from the center for CH_3I^{129}.

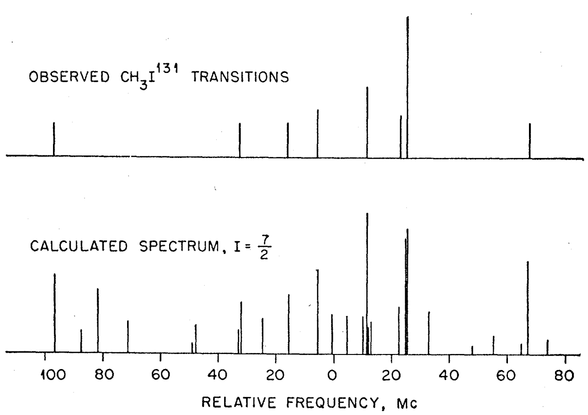

FIG. 1. Observed and calculated hyperfine structure for the $J=2\rightarrow3$ transition of CH_3I^{131}. Several of the weaker, calculated lines are off the ends of the figure.

The above coupling and the coupling value of -1934 Mc/sec[1] for CH_3I^{127} gives a quadrupole moment ratio of

TABLE I. Observed and calculated hyperfine structure for CH_3I^{131} relative to hypothetical $J=2\rightarrow3$ transition. $I=7/2$, $eqQ=-973$ Mc/sec, $D_{JK}=0.0994$ Mc/sec.

$K, F\rightarrow F'$	Calculated Mc/sec	Observed Mc/sec	|Calc| − |Obs| Mc/sec
2,9/2→11/2 2,9/2→9/2 2,9/2→7/2	−96.71	−96.65	+0.06
1,7/2→9/2	−32.13	−32.40	−0.27
0,7/2→9/2	−15.56	−16.01	−0.45
1,9/2→11/2	−5.56	−5.76	−0.20
0,11/2→13/2	11.58	[a]11.58	0.00
2,5/2→5/2 2,5/2→7/2 2,5/2→3/2	22.43	[b]23.01	+0.58
0,9/2→11/2 0,3/2→1/2	24.82	[b]25.11	−0.29
1,11/2→13/2	25.46		+0.35
2,11/2→11/2 2,11/2→13/2 2,11/2→9/2	67.11	67.55	−0.44

[a] Normalized to match at this frequency.
[b] CH_3I^{129} lines were unresolved from these lines.

$Q(I^{131})/Q(I^{127})=0.5031$. With $Q(I^{129})/Q(I^{127})=0.701213$[2] it is apparent that the magnitude of the quadrupole moment in the sequence $I^{127}:I^{129}:I^{131}$ varies as 1.0000: 0.7012:0.5031. The magnitude of the moment appears to approach a minimum as I^{135} (full neutron shell) is approached.[3] Using Jaccarino, King, and Stroke's[4] recent atomic-beam value $Q(I^{127})=-0.819\times10^{-24}$ cm^2 the quadrupole moment of I^{131} is -0.412×10^{-24} cm^2. The spin of 7/2 is consistent with recent β-decay studies.[5]

All of the chemical operations[6] for synthesizing CH_3I were carried out by remote control, and observations

† The work by Oak Ridge National Laboratory was performed for the U. S. Atomic Energy Commission. The work by Duke University was supported by the United States Air Force under a contract monitored by the Office of Scientific Research, Air Research and Development Command.

[1] Gordy, Simmons, and Smith, Phys. Rev. **74**, 243 (1948).
[2] R. Livingston and H. Zeldes, Phys. Rev. **90**, 609 (1953).
[3] W. Gordy, Phys. Rev. **76**, 139 (1949).
[4] Jaccarino, King, and Stroke (to be published).
[5] R. E. Bell and R. L. Graham, Phys. Rev. **86**, 212 (1952).
[6] Details will be published elsewhere.

were made on the oscilloscope of a video type microwave spectrometer. Relative line frequencies were measured with frequency markers derived from a stabilized microwave oscillator. We plan to measure the magnetic moment of I^{131}. In view of the decreased magnitude of Q and the same spin as I^{129} it will be interesting to see if the magnetic moment decreases.[3]

The I^{131} was obtained from the isotope production division at Oak Ridge National Laboratory. We wish to acknowledge the help of O. R. Gilliam in the early phases of the work.

Note added in proof:—In later work the $K=1$, $F=9/2\rightarrow 9/2$ and the $K=2$, $F=7/2\rightarrow 7/2$, $7/2\rightarrow 5/2$, $7/2\rightarrow 9/2$ lines were seen at frequencies in good agreement with those calculated from the parameters of Table I.

PHYSICAL REVIEW VOLUME 92, NUMBER 5 DECEMBER 1, 1953

Photoproduction of π-Meson Pairs*

R. D. LAWSON
Stanford University, Stanford, California
(Received August 25, 1953)

A perturbation study of the photoproduction of π-meson pairs by gamma rays incident on protons is made for both pseudoscalar and pseudovector coupling. Expressions are derived for the possible cross sections assuming the nucleon is infinitely heavy. The effect of first-order nucleon recoil on the (π^+, π^-) cross section, assuming pseudoscalar coupling, is considered. Curves illustrating the results are given. The possibility of obtaining information on the type of interaction operative between mesons and nucleons from a study of the pair production cross sections is discussed.

INTRODUCTION

ALTHOUGH the pseudoscalar nature of the π meson has been more or less definitely established,[1] the question of the coupling between the meson and nucleon fields remains unanswered. It is well known[2] that the pseudoscalar and pseudovector interactions give identical results to lowest order in the coupling constant provided $f=(2M/\mu)g$; where f and g are the pseudoscalar and pseudovector coupling constants respectively, and M and μ are the nucleon and meson masses. Assuming weak coupling theory to be approximately valid we must, therefore, study processes which do not proceed in lowest order of the coupling constant in order to gain insight into the type of interaction operative between mesons and nucleons.

Kaplon[3] has investigated the cross section for the production of π mesons in nucleon-nucleon collisions. His calculations indicate that the differential cross sections for the production process differ when the two types of coupling are used. However, aside from the assumption of weak coupling theory, the interaction between the two final state nucleons is neglected and consequently one cannot draw quantitative conclusions from the calculation.

This latter difficulty is partly obviated when we consider the photoproduction of π-meson pairs by gamma rays incident on protons.[4] It has been shown[5] that in the low-energy region the (π^+, π^-) and (π^0, π^0) cross sections for pseudoscalar coupling are considerably larger than those for the pseudovector interaction. On the other hand, the (π^+, π^0) cross section has approximately the same magnitude when either type of coupling is used. In this paper we shall investigate the possibility of obtaining information on the meson-nucleon interaction from a study of the photoproduction of meson pairs.

(π^+, π^-) PAIR PRODUCTION

A. Pseudoscalar Coupling

Assuming pseudoscalar coupling, the interaction energy between the meson, nucleon, and electromagnetic field is written as[6]

$$H=\int H_1 d\mathbf{r}+\int H_2 d\mathbf{r}+\int H_3 d\mathbf{r},$$

where

$$H_1 = if\bar{\psi}\gamma_5\tau_\alpha\phi_\alpha\psi,$$

$$H_2=-eA_\nu\left(\phi_1\frac{\partial\phi_2}{\partial x_\nu}-\phi_2\frac{\partial\phi_1}{\partial x_\nu}\right), \quad (1)$$

$$H_3=-ie\bar{\psi}\gamma_\nu A_\nu\tau_p\psi,$$

* Assisted by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research, Air Research and Development Command.

[1] R. E. Marshak, *Meson Phyics* (McGraw-Hill Book Company, Inc., New York, 1952), pp. 1–201.

[2] F. J. Dyson, Phys. Rev. **73**, 929 (1948); L. L. Foldy, Phys. Rev. **84**, 168 (1951); G. Wentzel, Phys. Rev. **86**, 802 (1952); S. D. Drell and E. M. Henley, Phys. Rev. **88**, 1053 (1952).

[3] M. F. Kaplon, Ph.D. thesis, University of Rochester, 1951 (unpublished). Details of the calculation are given by R. E. Marshak, reference 1, p. 47.

[4] The possibility of a strong attractive interaction between the emerging π mesons has been pointed out by K. A. Brueckner and K. M. Watson, Phys. Rev. **87**, 621 (1952).

[5] R. D. Lawson and S. D. Drell, Phys. Rev. **90**, 326 (1953).

[6] Throughout this work the system of units in which $\hbar=c=1$ will be used. The fine structure constant in our notation is $e^2/4\pi$ and the meson-nucleon coupling constant is $f^2/4\pi$.