Results to date, while still of a preliminary nature, indicate that $0.10<R<0.13$. Final results will be reported in more detail at a later date.

This paper is based on work performed under the auspices of the AEC.

[1] Rumbaugh, Roberts, and Haĭstad, Phys. Rev. **54**, 657 (1938).

Exchange Phenomena of the Nucleons That Generate Penetrating Showers

H. A. MEYER AND G. SCHWACHHEIM
Departmento de Fisica, Universidade de São Paulo, São Paulo, Brasil
February 23, 1949

RECENTLY G. Cocconi performed measurements on the absorption of ionizing PSPR* (which are believed to be protons) in Pb, Fe, C, and air.[1] He finds that this absorption is not exponential in the condensed absorbers and that the mean range of ionizing PSPR in the atmosphere increases with the lead thickness above the penetrating shower detector. These results are not compatible with an exponential absorption of the PSPR which was verified by Tinlot and Gregory[2] in Pb and Fe and by Wataghin[3] and Tinlot[4] in the atmosphere.

The fundamental difference between the experimental arrangement of Cocconi and those of the other authors, is that a proton of the PSPR appears as absorbed in any material situated in position Σ (Fig. 1 of Cocconi's paper[1]), not only when it generates a penetrating shower, but also when it emerges from Σ in the form of a neutron.

Let us discuss Cocconi's results by taking into account the phenomenon described above. We shall make the following hypothesis: (1) The absorption of nucleons through production of penetrating showers is exponential in all materials and is independent of their charge as well as of the altitude of the point of observation. (2) The probability of a transformation of a proton into a neutron is equal to that of the reverse process. (3) At Echo Lake (708 g/cm^{-2}) the number of protons is already equal to the number of neutrons in the PSPR. Indeed, if this were not so, Cocconi should have found a mean range for the ionizing PSPR in the atmosphere (without any absorber above the detector) smaller than the mean range of the total PSPR determined by Wataghin and Tinlot. Thus varying the absorber thickness at position Σ' in Cocconi's experiments[1] and the absorber thickness in the arrangement of Tinlot and Gregory,[2] it is only necessary to consider the exponential absorption due to the production of penetrating showers.

Following this interpretation one deduces easily from Cocconi's measurements the values of the mean range λ for the production of penetrating showers in different absorbers:

$$\lambda_{Pb}=345\pm37 \text{ g/cm}^{-2},$$
$$\lambda_{Fe}=240\pm27 \text{ g/cm}^{-2},$$
$$\lambda_{C}=100\pm12 \text{ g/cm}^{-2},$$
$$\lambda_{Air}=113\pm7 \text{ g/cm}^{-2},$$

in good agreement with the values given by other workers.[2-4] A short calculation yields for the mean range μ for charge exchange the values

$$\mu_{Pb}=247\pm61 \text{ g/cm}^{-2},$$
$$\mu_{Fe}=300\pm121 \text{ g/cm}^{-2},$$

at Echo Lake (708 g/cm^{-2}). For μ_C we obtain a larger value than the preceding ones, but the statistical errors are too important to allow a precise determination. However this result is not surprising since charge exchange and shower production are competititive processes. It is then reasonable to expect that μ should increase if λ decreases. At Ithaca (1007 g/cm^{-2}) μ is found to be several times larger, but a precise determination is impossible.

We see that the exchange properties of the PSPR explain Cocconi's results consistently with the results of other authors. On the other hand we wish to point out that the energy loss of the protons by ionization has been neglected, and this might not be very accurate in the case of the rather low energy events recorded by Cocconi[1] and by Tinlot and Gregory.[2] However, we think that this factor could at most alter somewhat the numerical values of the mean ranges.[5]

* We use the abbreviation PSPR for Penetrating Shower Producing Radiation.

[1] G. Cocconi, Phys. Rev. **75**, 1074 (1949). We are indebted to Professor Cocconi for having communicated to us his results before publication.
[2] J. Tinlot and B. Gregory, Phys. Rev. **75**, 519 (1949).
[3] G. Wataghin, Phys. Rev. **71**, 453 (1947).
[4] J. Tinlot, Phys. Rev. **74**, 1197 (1948).
[5] A more complete account will appear in the Anais da Acad. Bras. de Cienc.

The Nuclear Spin and Quadrupole Moment of I^{129}

RALPH LIVINGSTON
Oak Ridge National Laboratory, Oak Ridge, Tennessee*
AND
O. R. GILLIAM AND WALTER GORDY
*Department of Physics, Duke University,** Durham, North Carolina*
May 19, 1949

THE nuclear spin and quadrupole moment of I^{129} have been determined from measurements on the $J=2\rightarrow3$ rotational transition of CH_3I^{129}, which occurs in the 6.75 millimeter wave region. As is apparent from observation of Fig. 1, the spin of I^{129} is unquestionably 7/2. The very large number of absorption lines which are found in the hyperfine structure make it impossible to fit the theoretical pattern of any other spin to the observed data. The theoretical plots shown include only first order theory.

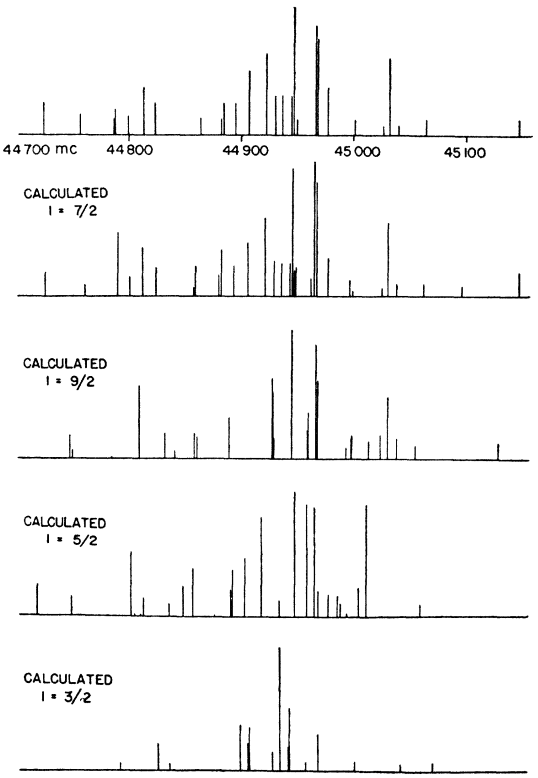

FIG. 1. Observed and calculated hyperfine structure for the $J=2\rightarrow3$ transition of CH_3I^{129}.

Because of the large quadrupole coupling found for this molecule, $eQ\partial^2V/\partial z^2=-1422$ mc, second order effects[1] cause slight deviations of the observed from the calculated spectrum for 7/2 spin. For example, these effects make one of the lines appear as a doublet, which according to first order theory would be a single line, composed of three components.

The quadrupole moment of I^{129} is negative—that is, the nucleus is oblate, or flattened along the spin axis. The ratio of $Q(I^{129})$ to $Q(I^{127})$ is 0.7353. If the quadrupole moment of I^{127} from atomic spectra,[2] -0.46×10^{-24} cm^2, is used, the value for the quadrupole moment of I^{129} is determined as -0.34×10^{-24} cm^2. With the value of -0.59×10^{-24} cm^2 for the quadrupole moment[3] of I^{127}, obtained from microwave measurements[4] for CH_3I^{127}, the quadrupole moment of I^{129} is found to be -0.43×10^{-24} cm^2. We are inclined to favor the latter value, which depends on the calculation of $\partial^2V/\partial z^2$ from the doublet separation of iodine, according to the formula[5]

$$\partial^2V/\partial z^2=8e\Delta\nu/15Z_iR\alpha^2a_0^3.$$

The C—I bond in methyl iodide is close to a pure single bond formed by a p-orbital of the iodine. The bond should have very little ionic character since the electro-negativities of iodine and carbon are approximately equal. Hence, the application of this formula to methyl iodide should give a more accurate value of the $\partial^2V/\partial z^2$ than it would when applied to ICN, where the C—I bond is complicated by appreciable resonance with double bond structures, or to ICl, where there is a fairly large electro-negativity difference of the bonded atoms.

I^{129} is known to emit beta-rays and to decay to Xe^{129}, with a long half-life.[6] Since the spin of Xe^{129} is $\frac{1}{2}$, the spin change in this reaction is therefore 3. The long half-life of I^{129} is consistent with this spin change, and its spectrum should be of the second forbidden type or higher.

We are now attempting to determine the nuclear magnetic moment of I^{129} from the Zeeman effect on the hyperfine structure and are using the present data to obtain a more accurate determination of the structure of the methyl iodide molecule. This information, with details on experimental procedure, will be given in a later publication.

We wish to acknowledge the help of Mr. George Parker and Mr. Gordon Hebert of the Chemistry Division, Oak Ridge National Laboratory, who isolated the I^{129} from fission material.

* The work at Oak Ridge National Laboratory was performed under Contract Number W-7405 eng. 26 for the Atomic Energy Project.

** The work at this institution was supported by Contract Number W-19-122-ac-35 with the U. S. Air Force, Cambridge Field Station.

[1] Gilliam, Edwards, and Gordy, Phys. Rev. **73**, 635 (1948); J. Bardeen and C. H. Townes, Phys. Rev. **73**, 627, 1204 (1948).
[2] K. Murakawa, Zeits. f. Physik **114**, 651 (1939); T. Schmidt, Zeits. f. Physik **113**, 140 (1939).
[3] W. Gordy, Rev. Mod. Phys. **20**, 714 (1948).
[4] Gordy, Simmons, and Smith, Phys. Rev. **74**, 243 (1948).
[5] H. A. Bethe and R. F. Bacher, Rev. Mod. Phys. **8**, 226 (1936); C. H. Townes, Phys. Rev. **71**, 909 (1947).
[6] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948); personal communication with Mr. George Parker; details to be published at a later date.

Nuclear Magnetic Moments and Hyperfine Structure of the Rubidium Isotopes*

F. BITTER
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts
May 23, 1949

A RECENT determination[1] of the nuclear moments of the rubidium isotopes indicates that, as was first suspected by Millman and Kusch,[2] the observed ratio of the magnetic moments does not agree with the ratio calculated from hyperfine structure,

$$\mu\,Rb^{87}/\mu\,R^{85},$$

Observed	(1)	2.0327±0.001
Observed	(3)	2.038 ±0.01
Calculated	(2)	2.0261±0.0003.

The interaction between the optical electron and the nucleus is of two kinds—electrostatic and magnetic—and it is of interest to determine whether the observed effect can be accounted for on the basis of either of these two forces. The effect of spreading the nuclear charge, usually considered concentrated at a point at the origin, over a finite sphere of radius R_0, is to reduce the electronic density $\psi^2(0)$ at the nucleus. This effect was shown by Rosenthal and Breit[4] to lead to a correction in calculating hyperfine structure of the order of zR_0/a_0 for atoms having a nuclear charge in the range of rubidium. The a_0 is the radius of the first Bohr hydrogen orbit. While this ratio is 0.5 percent for rubidium, and can account for discrepancies in the hyperfine structure of the order of the observed discrepancy (0.3 percent), it is very unlikely that this is the explanation, as it would require an enormous difference in size of Rb^{85} and Rb^{87}. Besides the fact that all available evidence supports a slowly varying nuclear radius proportional to the cube root of the mass number, we have specific evidence[5] that there is no observable isotope shift in the spectrum of rubidium, and therefore no such very large difference in nuclear size. Effects due to a magnetic structure inside the nucleus, first proposed by Kopfermann[6] in the days when such effects could well be dismissed as negligible, and recently applied by Bohr[7] to the proton-deuteron problem, also lead to a correction of the order of zR_0/a_0. This is a much more reasonable explanation, since there is no objection to assuming the wave function for the odd proton in rubidium to be quite different for the two isotopes. In fact, this might be expected on the basis of a vector model[8] of the nucleus, which would assign to Rb^{87} with $I=3/2$, $l+s=1+1/2$, and to Rb^{85} with $I=5/2$, $l-s=3-1/2$.

The fact that effects of this order of magnitude have not been observed for the gallium isotopes[9] or for the thallium isotopes[10] is not unreasonable since, in both cases, the two isotopes have the same nuclear spin and comparable nuclear moments, and it is therefore not unreasonable to assume that they also have comparable wave functions for the odd proton.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and the ONR.
[1] F. Bitter, Phys. Rev. **75**, 1326 (1949).
[2] Millman and Kusch, Phys. Rev. **58**, 438 (1940).
[3] Kusch and Millman, Phys. Rev. **56**, 527 (1939).
[4] Rosenthal and Breit, Phys. Rev. **41**, 459 (1932).
[5] Kopfermann and Kruger, Zeits. f. Physik. **103**, 48J (1936).
[6] H. Kopfermann, *Kernmomente* (Akademische Verlagsgesellschaft, M.B.H., Leipzig, 1940), p. 17.
[7] A. Bohr, Phys. Rev. **73**, 1109 (1948).
[8] See, for example, Brookhaven National Laboratory publication 1-5, by Goldsmith and Inglis, on "Spins, Magnetic Moments, and Electric Quadrupole Moments," dated October 1, 1948.
[9] R. B. Pound, Phys. Rev. **73**, 1112 (1948).
[10] H. Poss, Phys. Rev. **75**, 600 (1949).

Hall Effect in Metal-Semiconductor Point Contacts

S. BENZER
Department of Physics, Purdue University, Lafayette, Indiana*
May 18, 1949

TRANSVERSE Hall effect determinations have been a very useful tool in the study of conductivity in bulk semiconductors. According to the elementary theory of the Hall effect, if a current I passes through a parallelepiped (Fig. 1(a)) and a perpendicular magnetic field H is applied, a transverse e.m.f. is observed given by the formula $E=RHI(1/t)$, where t is the thickness of the specimen (in the H direction) and R is a constant characteristic of the material. The magnitude and sign of R yield information regarding the density of current carriers and whether they are predominantly electrons or holes; studies of Hall effect