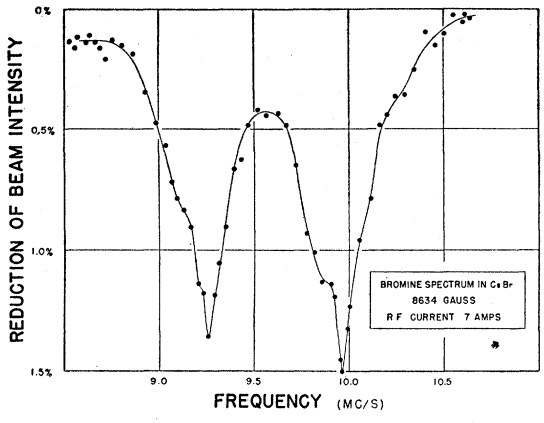

FIG. 1. Reduction in beam intensity as a function of oscillator frequency.

ratio

$$g_I = h\nu/\mu_N H, \tag{1}$$

where μ_N is the nuclear magneton.

As will be discussed in a later paper by one of us (N.F.R.), there are certain special circumstances in the case of very large nuclear electrical quadrupole-moment interactions when the frequency of an observed resonance minimum may be double that of Eq. (1). This possibility is excluded in the present experiments by comparison with optical fine-structure experiments of Tolansky[3] interpreted by Schmidt[4] which indicate a value of 2.6 nuclear magnetons for bromine in fair agreement with our observed values using Eq. (1) and in marked disagreement if values of the frequency double that given in (1) are used. Furthermore, the integrated intensity of the resonance minima in Fig. 1 is greater than would be expected for a resonance of double the frequency of Eq. (1) and is approximately correct for a normal resonance.

With (1) being used to determine the gyromagnetic ratios and with the spins of the bromine isotopes taken to be[3,5] $\frac{3}{2}$, the magnetic moments of the bromine isotopes are 2.110 ± 0.021 and 2.271 ± 0.023 nuclear magnetons. Since each isotope is present in about 50 percent abundance, it is impossible from the present experiments to assign specific isotopes to the different observed moments.

Although the resonance minima are quite broad they do not possess the characteristic shape for a nuclear electrical quadrupole interaction with spin[2,6] $\frac{3}{2}$. This is somewhat surprising in view of the large quadrupole interaction of Br in BrCN found by Townes.[5] The spectra correspond more nearly to those of an arbitrarily assumed $\mathbf{I}\cdot\mathbf{J}$ interaction which has been found useful in accounting for some other resonance-minima curves. Further studies of the shape and interpretation of the bromine resonance are being made.

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[1] I. I. Rabi, S. Millman, P. Kusch, and J. R. Zacharias, Phys. Rev. **55**, 526 (1939).
[2] W. A. Nierenberg, N. F. Ramsey, and S. B. Brody, Phys. Rev. **70**, 773 (1946).
[3] Tolansky, Proc. Roy. Soc. **A136**, 585 (1932).
[4] T. Schmidt, Zeits. f. Physik **108**, 408 (1938).
[5] C. H. Townes, A. N. Holden, J. Bardeen, and F. R. Merritt, Phys. Rev. **71**, 644 (1947).
[6] B. T. Feld and W. E. Lamb, Jr., Phys. Rev. **67**, 15 (1945).

Millimeter-Wave Spectra: Hyperfine Structure of BrCN and ICN*

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USING the method prevously described,[1] we have examined the $J=3$ to $J=4$ transition of BrCN and the $J=4$ to $J=5$ transition of ICN, both of which occur in the region of 9 mm. As was discovered by Townes[2] in the $J=2$ to $J=3$ transition of BrCN, Br has a rather large quadrupole moment which splits the pure rotational lines into a number of components. In our laboratory the quadrupole moment of the iodine nucleus has been observed through the splitting of the rotational lines of methyl iodide[3] as well as through the hyperfine structure of ICN reported here.

The quadrupole-moment effects were first noticed in atomic spectra, and the interaction was shown by Schuler and Schmidt[4] to be proportional to the square of the cosine of the angle between the angular momentum vector of the orbital electron and the nuclear spin vector. Casimer,[5] and also Bethe[6] have derived a theory for the quadrupole effects in atomic spectra. This theory as well as the intensity rules derived for atomic fine structure[7] has been adapted to the analysis of the molecular hyperfine structure reported here.

In Figs. 1 and 2 are shown the calculated and observed hyperfine spectra for BrCN and ICN. The calculated lines are given for the ground vibrational states only, although in both these molecules lines caused by excited vibrational states were observed. These are indicated in the experimental diagrams by lighter lines. The lines on the low frequency side are caused by the vibration which corre-

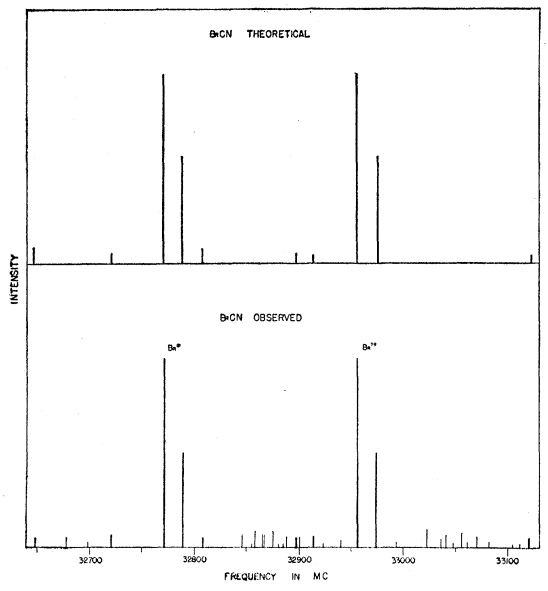

FIG. 1. Theoretical and observed hyperfine structure of the BrCN spectrum for the rotational transition $J=3$ to $J=4$. The heavy lines are for the ground vibrational state; the light ones in the observed spectrum are due to excited vibrational states.

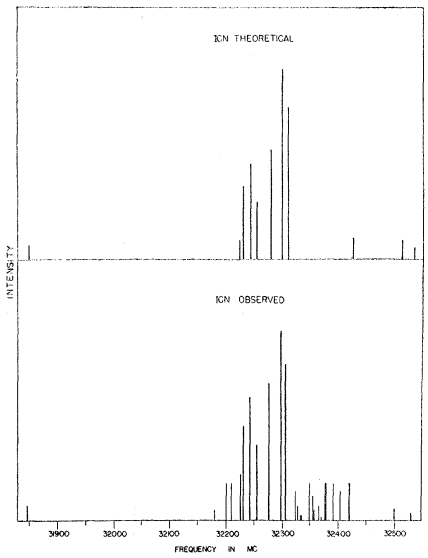

FIG. 2. Theoretical and observed hyperfine structure of the ICN spectrum for the rotational transition $J=4$ to $J=5$. The heavy lines are for the ground vibrational state; the light ones in the observed spectrum are due to excited vibrational states.

sponds to the stretching of the carbon-halogen bond, and in each case the stronger lines in the ground state are repeated with identical spacing in the excited vibrational state. From the separation of these groups it is possible to calculate the increase in the average bond length in the excited state over that for the ground state. They are: for BrC 0.0029A (0.17 percent increase); for IC 0.0037A (0.18 percent increase). This increase in length is due to the anharmonicity of the bond-stretching potential function. In the bending vibrational state the molecule is on the average shorter and the moment of inertia smaller. Hence, these lines fall on the high frequency side. Because of the interaction of the two modes of bending (L-type doubling) the hyperfine pattern of the ground state is not repeated exactly, as it is for the stretching vibration.

The moment of inertia and the structure of the BrCN molecule have been determined by Townes[2] from the rotational lines occurring at the lower frequencies. Our values for this molecule agree with his. The moment of inertia of ICN in its ground vibrational state is determined from our data as 260×10^{-40} g cm^2. Assuming the CN distance to be that observed for BrCN and ClCN (1.15A), the CI distance is 2.00A. No measurements from other sources are available for comparison, but this value should be accurate to 1 percent at least. To determine the structure of this molecule completely, we plan to search for the carbon isotope which should be detectable by our method.

The spin of the iodine nucleus is definitely established as 5/2. The quadrupole coupling factors, $eQ\partial^2V/\partial z^2$, are: for Br^{79}, 670±15 Mc; for Br^{81}, 567±15 Mc; for I^{127}, 2070±20 Mc. The quadrupole moment of I is negative, indicating that the iodine nucleus is flattened in the direction of the spin axis, i.e., it is oblate. That of Br is positive, indicating that the Br nucleus is elongated in the direction of the axis of spin, i.e., it is prolate. When the coupling coefficient $\partial V^2/\partial z^2$ is evaluated, the quadrupole moments of I and of Br can be determined from this data. We are now attempting to evaluate $\partial^2V/\partial z^2$ from data of other types.

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** Frederick Gardner Cottrell Fellow.

[1] W. Gordy and M. Kessler, Phys. Rev. **71**, 640 (1947).
[2] C. H. Townes, A. N. Holden, and F. R. Merritt, Phys. Rev. **71**, 64 (1947); and with J. Bardeen, Phys. Rev. **71**, 664 (1947).
[3] W. Gordy, A. G. Smith, and J. W. Simmons, Phys. Rev. **71**, 917(L) (1947); see also the note on CH_3I in this issue.
[4] H. Schuler and Schmidt, Zeits. f. Physik **94**, 457 (1935).
[5] H. von Casimer, Physica **2**, 719 (1935).
[6] H. Bethe and R. F. Bacher, Rev. Mod. Phys. **8**, 82 (1936).
[7] H. E. White and A. Y. Eliason, Phys. Rev. **44**, 753 (1933).

On the Inelastic Scattering of Neutrons in Crystals*

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THE inelastic scattering of a monochromatic neutron beam by crystal powders has been studied extensively by C. G. Shull and E. O. Wollan[1]; the experimental technique followed closely the well-known procedure in x-ray experiments. The very remarkable results obtained by these authors with a variety of scatterers seem to be in quantitative, and even qualitative disagreement with the presently accepted theories. It is, therefore, perhaps of interest to indicate an experimental approach to this problem which has no analogy in x-ray technique and promises to give valuable independent information. We suggest the study of the transmission of monochromatic neutron beams through single crystals of iron in a transverse magnetic field. Theory[2] then predicts very precisely that (apart from special angles of incidence here left out of consideration) no coherent scattering will occur. The weakening of the beam is due to incoherent nuclear scattering, inelastic lattice scattering, isotope disorder effects, and capture. Of these effects only inelastic lattice scattering will be influenced by a magnetic field. This special polarization effect has its origin in the fact that the incoherence of the inelastic scattering is due to energy exchange with the lattice while no element of incoherence enters into the interaction with the individual atom. Here the amplitudes of the wave scattered by the nucleus and by the magnetically active electron shell, superpose in the same way as we know them to interfere in the well-studied polarization effects obtained with polycrystalline iron.

In the present experiment the difference in transmission in the unmagnetized and saturated state of the scatterer is measured. This difference, $\Delta I/I$, will again be given in the customary approximation by the well-known formula

$$\Delta I/I=\tfrac{1}{2}p'^2d^2. \qquad (1)$$

In (1) p' denotes the excess cross section arising from the