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RADIO SPECTRUM OF SH[†]

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Diatomic molecules are present in interstellar gas, and they should be detectable with existing radio telescopes once their radio spectra become known. Especially likely candidates are the diatomic radicals OH, CH, SiH, and SH which, because of the Λ-type doublet structure of their ground states, possess electric dipole radio spectra of exceptional intensity. Because of the chemical instability of these radicals under laboratory conditions, measurements of their radio spectra are difficult and so far have been successful only for the relatively long-lived OH radical.[1-3] Recently McDonald[4] has discovered a method suited to the continuous production of SH radicals in a low-pressure gas, and it has become possible to measure the Λ-type doubling spectrum of SH to high precision. The detection method used by McDonald was that of paramagnetic resonance absorption, and we have used the same method in the precise measurements reported here. By subjecting the gas sample to a magnetic field, one can shift the low-frequency Λ-type doubling transitions to a conveniently high microwave band, where they may be measured with maximum sensitivity.

SH radicals were generated by adding hydrogen sulfide to the products of an electric discharge in hydrogen gas. The mixing was done at the center of a quartz absorption cell which lined the microwave cavity of an X-band superheterodyne paramagnetic resonance spectrometer. Absorption signals were observable at total pressures that ranged from several mm Hg down to approximately 0.1 mm Hg. The signal intensities depended critically on the relative flow rates of H_2 and H_2S, the best mixture being that which reduced the atomic hydrogen concentration to zero (as judged by the intensity of the atomic hydrogen resonance spectrum). The inlet hydrogen was bubbled through water to aid in maintaining the electric discharge at low pressure. Water vapor alone, when substituted for the wet hydrogen, gave reduced amounts both of atomic hydrogen and of SH.

A derivative recording of the SH spectrum, taken with a synchronous detector of time constant 1 sec, is shown by Fig. 1. The total pressure for this recording was about $\frac{1}{4}$ mm Hg; the lines are pressure broadened to a width of 0.4 gauss, equivalent to a frequency width of 0.5 Mc/sec. The total intensity in this spectrum is approximately one tenth of that in the two-line atomic hydrogen spectrum, observed under conditions that were identical but for the absence of H_2S. Fig. 1 has all the characteristic features expected for the Zeeman spectrum of SH in its ground $^2\Pi_{3/2}$, $J=\frac{3}{2}$ level, and a spectral analysis may be made in

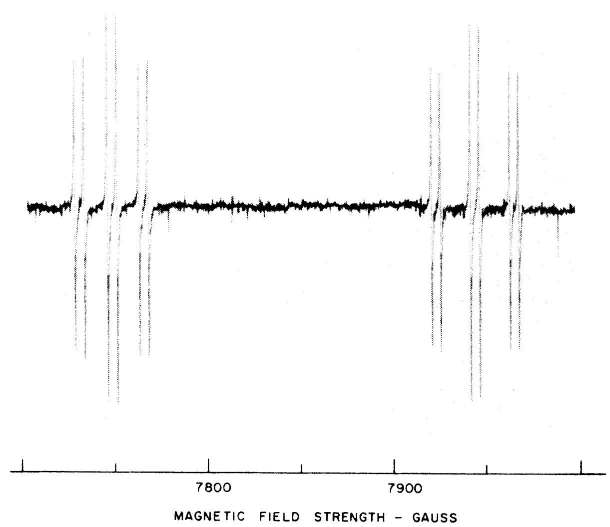

FIG. 1. Paramagnetic resonance spectrum of free SH radicals in the ground $^2\Pi_{3/2}$, $J=\frac{3}{2}$ state. Microwave frequency: 9216 Mc/sec.

Table I. Molecular g factor, Λ-type doubling frequency, and hyperfine structure coupling constants of the ground $^2\Pi_{3/2}$, $J=\frac{3}{2}$ state of SH.

	Experiment			Theory
g_J	0.83792	±0.00002		0.8380 [a]
ν_Λ	111.42	±0.04	Mc/sec	114 Mc/sec [b]
$\|A_1\|$	5.61	±0.04	Mc/sec	
$\|A_2\|$	0.08	±0.04	Mc/sec	

[a]Calculated from optical data of D. H. Ramsay, J. Chem. Phys. 20, 1920 (1952).

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exactly the same way as for the corresponding spectrum of OH.[3] In qualitative terms, the overall location of the spectrum in magnetic field strength indicates the size of the molecular magnetic moment, while the separation of the two groups of lines is a measure of the Λ-type doubling interval. Each group contains three hyperfine structure doublets, which are separated from one another by a second-order Zeeman effect.

The major results of a detailed spectral analysis are given by Table I, which also gives comparable theoretical results calculated from optical data.

In the absence of a magnetic field, the twelve-line spectrum of Fig. 1 would condense into two strong closely spaced lines, plus two weak satellites. The complete zero-field spectrum can be calculated, with no approximations, from the data of Table I and relations found in references 2 and 3. The frequencies of the two strong ($\Delta F=0$) lines, which will serve to identify interstellar SH, are given by $\nu_\Lambda \pm 2A_2$, and are

$$\nu_1 = 111.26 \pm 0.10 \text{ Mc/sec } (F=1 \rightarrow F=1),$$

$$\nu_2 = 111.58 \pm 0.10 \text{ Mc/sec } (F=2 \rightarrow F=2),$$

with expected relative intensities of 5 for $F=1$ and 9 for $F=2$.

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MEASUREMENT OF THE DEPOLARIZATION PARAMETER FOR 50-MeV PROTON-PROTON SCATTERING AT 70° c.m.

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The phase shifts characterizing the proton-proton interaction at energies below 310 MeV are now known with reasonable precision,[1] except in the energy region between 20 and 90 MeV, where the absence of triple scattering data precludes the determination of a unique set of phase shifts. In particular, at 50 MeV, where only the differential cross section[2] and polarization[3] are known, the $^3P_0$ phase shift can vary over a range of almost 30° without appreciably altering the fit to the experimental data.[4] The depolarization parameter is very sensitive to the magnitude of this phase shift, and a single measurement of this parameter at 50 MeV would determine the $^3P_0$ phase shift to considerably higher accuracy.[5] This Letter describes such a measurement recently completed at the Rutherford Laboratory, Harwell, England.

The experimental arrangement is shown in Fig. 1. The 50-MeV vertically polarized proton beam from the linear accelerator is focused on a liquid hydrogen target (A) and protons scattered at 35° to the left and right enter polarization analyzers (B) containing high-pressure helium gas in which a second scatter can occur. Inside the analyzers, scattering angles of 60°± 15° are defined by a system of copper vanes (C), and protons are detected in plastic scintillator strips (D) viewed from one end by photomultipliers (E). Protons entering an analyzer traverse a thin counter (F) between target and analyzer, and fast coincidences between this counter and each of the counters in the analyzer are recorded.

The contribution of background to the observed

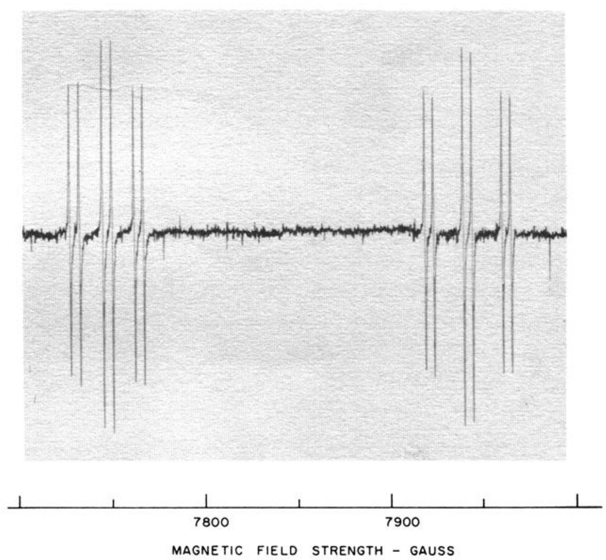

FIG. 1. Paramagnetic resonance spectrum of free SH radicals in the ground $^2\Pi_{3/2}$, $J = \frac{3}{2}$ state. Microwave frequency: 9216 Mc/sec.