



FIG. 2. Wave-guide assembly with fixed coupling holes. End plate shown retracted.

bismuth for instance, are opposite in sign to the predicted rotation on the basis of the above assumption. This suggests the possibility of more than one mechanism for the observed effect.

2. All rotations produced by magnetic fields are accompanied by time-phase shifts relative to the primary current. In other words, the reflected wave is elliptically polarized.

3. Since any asymmetry of the resonant cavity gives rise to coupling between the two above-mentioned modes of oscillation, great care must be taken with machining operations and preparation of specimens. Random scratches resulting from polishing the specimen surfaces cause no effect but any regularity resulting from polishing produces a residual rotation. No time-phase changes result from rotations produced by mechanical asymmetry.

4. Transverse (perpendicular to the cavity axis) magnetization of ferromagnetic specimens, in general, produces a rotation in the absence of any external magnetic field. Effects of this type are easily detected by mechanically rotating the specimen relative to the cavity.

The preliminary measurement of rotation was made in the apparatus shown in Fig. 1, in which the homogeneity of the magnetic field was not better than 10 percent. The angle of rotation increases with magnetic field strength but in such a field it is easily possible that fine structure with respect to field strength be unresolved.

The cavity shown in Fig. 2 sacrifices the feature of relative rotation of coupling holes in order to reduce the over-all axial length of the cavity, and hence permits its use in a magnet of more uniform field strength.

Since some part of the observed effects may be due to electron spin transitions, and since such transitions are in the nature of precessional rotations, it was reasonable to

suppose that a ferromagnetic salt crystal would produce similar rotations. In order to test the sensitivity of the apparatus, a 50-mg specimen of dilute iron alum (0.0085: iron to aluminum) was symmetrically mounted in a cavity of the type shown in Fig. 2. Operating at 9310 Mc/sec. (the resonance frequency of the cavity) with magnetic fields in the vicinity of 3360 gauss, the main resonance and two satellite lines were observed.

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### Atmospheric Absorption of Water Vapor between 1.42 $\mu$ and 2.50 $\mu$

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IN our high resolution recordings of the infra-red solar spectrum<sup>1</sup> there appear a very large number of lines resulting from atmospheric water vapor. We have undertaken the rotational analysis of this material, and wish to report briefly on the principal results.

Between 1.34 $\mu$  and 1.42 $\mu$  there is complete absorption, due principally to the well-known perpendicular band ( $v_1v_2v_3 = 101$ ). At the long wave-length edge of this region there appears the perpendicular band (021).<sup>2</sup> It is well developed and well resolved on our spectra; it has been possible to locate most of the rotational levels up to  $J=9$ . It is overlapped to some extent by high  $J$  transitions in the  $P$  branch of (101) and its weaker satellite, the parallel band (200).<sup>3</sup> It is also overlapped at longer wave-lengths by a weaker, previously unreported parallel band (120), of which we have identified most of the rotational levels up to  $J=6$ . Practically all of the strongest lines between 1.42 $\mu$  and 1.54 $\mu$  have been accounted for by these four bands.

There is again complete absorption between about 1.82 $\mu$  and 1.97 $\mu$  caused by the strong perpendicular band (011), which is accompanied by the much weaker parallel band (110).<sup>3</sup> The short wave-length wing of this region is well resolved, and we have been able to assign the strongest lines, from 1.71 $\mu$  to 1.82 $\mu$ , to transitions of the type  $\Delta J = +1$ ,  $\Delta \tau = +3$ , for  $J$  up to 8, and  $\Delta J = +1$ ,  $\Delta \tau = -1$ , for  $J$  up to 11, in the (011) band. In the long wave-length wing, from 1.97 $\mu$  to 2.05 $\mu$ , the H<sub>2</sub>O absorption is complicated by strong bands of CO<sub>2</sub>, but some of the corresponding transitions with  $\Delta J = -1$  have been found, as well as lines of (110).

Between 2.00 $\mu$  and 2.22 $\mu$  a number of relatively weak lines have been identified as belonging to the parallel band (030), the previously unreported second overtone of

TABLE I.

$v_1$	$v_2$	$v_3$	$\nu_0$ cm <sup>-1</sup>	$A$ cm <sup>-1</sup>	$B$ cm <sup>-1</sup>	$C$ cm <sup>-1</sup>
0	2	1	6871.37	33.50	14.84	8.87
1	2	0	6775.00	34.43	14.67	8.78
0	3	0	4666.70	42.05	14.98	8.88

the bending fundamental. Most of the levels up to  $J=6$  have been found, but the analysis is complicated by the overlapping in the  $R$  branch with the stronger  $\text{CO}_2$  absorption. Further measurements with relatively large amounts of  $\text{H}_2\text{O}$  in the absorbing path are planned in order to develop this band more fully. The third overtone (040), which should fall in the relatively clear region  $1.54\text{--}1.64\mu$ , will also be sought under these conditions.

Between  $2.22\mu$  and  $2.50\mu$ , the latter being the approximate limit of complete absorption as a result of the strong  $\nu_3$  fundamental, resolved lines have been assigned principally to the  $\Delta J=+1$ ,  $\Delta\tau=+3$  transitions of that fundamental up to  $J=10$ . A few lines of the  $\Delta J=+1$ ,  $\Delta\tau=+7$  type have been located, and a number of the strong lines near  $2.5\mu$  doubtless result from the  $\Delta J=+1$ ,  $\Delta\tau=-1$  transitions, with  $J$  from 10 to 15, but definite assignments for these lines must await corresponding measurements in the long wave-length wing of the band.

The position of the zero rotational level and the approximate effective reciprocal moments of inertia for the three newly resolved bands are shown in Table I.

The relative intensities of the various bands may be estimated approximately, by comparing, for fully resolved lines of equal absorption in the several bands, the calculated intensities.<sup>4</sup> If the probability of vibrational transition in (001) is assigned the value 5000, the probabilities for the other bands are: (101)=80; (200)=20; (021)=8; (120)=1; (011)=150; (110)=3; (030)=1.

Further details of the analysis will be published by one of us, together with results obtained in the photographic region.<sup>5</sup>

<sup>1</sup> R. R. McMath, O. C. Mohler, and L. Goldberg, Phys. Rev. 73, 1203 (1948).

<sup>2</sup> T. G. Cowling, Nature 152, 694 (1943).

<sup>3</sup> R. C. Nelson and W. S. Benedict, following communication.

<sup>4</sup> P. C. Cross, R. M. Hainer, and G. W. King, J. Chem. Phys. 12, 210 (1944).

<sup>5</sup> W. S. Benedict, Bull. Am. Phys. Soc., 23, 54 (1948).

### Absorption of Water Vapor Between 1.34 $\mu$ and 1.97 $\mu$

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THE absorption of water vapor between  $1.34\mu$  and  $1.97\mu$  has been recorded using the PbS photoconductive cell with the spectrograph and amplifier described by Nelson and Wilson.<sup>1</sup> The absorption path within the spectrograph was 11 meters long, and the extent

TABLE I.

$v_1$	$v_2$	$v_3$	$\nu_0$ cm <sup>-1</sup>	$A$ cm <sup>-1</sup>	$B$ cm <sup>-1</sup>	$C$ cm <sup>-1</sup>
1	0	1	7249.8	25.89	14.12	8.98
2	0	0	7201.4	26.38	14.20	8.94
0	1	1	5331.2	29.52	14.61	8.98
1	1	0	5235.0	30.13	14.45	8.93

of absorption was controlled by varying the humidity in the instrument. There are two principal regions of absorption,  $1.34$  to  $1.48\mu$  and  $1.78$  to  $1.97\mu$ . In the former, the effective slit width was  $0.18\text{ cm}^{-1}$ ; this permitted 70 scale divisions deflection on the Speedomax recorder with a noise level (illuminated) of one division. In the longer wave-length region the lower sensitivity of the detector required slits of  $0.40\text{ cm}^{-1}$ .

The spectrum obtained bears a general resemblance to that previously reported,<sup>2</sup> but the resolution is markedly improved and there is a systematic deviation in the wave-lengths—our values, after correction to vacuum, being from  $1.5$  to  $2.0\text{ cm}^{-1}$  lower in the  $1.4\mu$ -region, and  $0.8$  to  $1.2\text{ cm}^{-1}$  lower in the  $1.9\mu$ -region. The present values, obtained by comparison with lines of Ne in higher orders, are believed accurate to  $\pm 0.1\text{ cm}^{-1}$ . Agreement to within this limit is found with measurements made with atmospheric path lengths with both photo-cell<sup>3</sup> and photographic<sup>4</sup> recording.

A rotational analysis of the lines has been made, using the known rotational levels of the ground state<sup>5</sup> to locate groups of lines with a common upperstate level. The calculated energy and intensity tables for the rigid asymmetric rotor<sup>6</sup> served as valuable guides in making the assignments. The principal absorption between  $1.36\mu$  and  $1.42\mu$  is due to the well-known perpendicular band ( $v_1v_2v_3=101$ ), but, as was found to be the case with corresponding bands in the photographic region,<sup>7</sup> there are many lines that must be attributed to a weaker band of parallel symmetry type (200). The relative intensity of the two bands is about 4:1, except for a few lines going to closely lying rotational levels of equal  $J$  and the same total symmetry, when perturbations of the Coriolis type occur, giving rise to displacements of the calculated term values and enhancement of the intensity of the weaker band. The rotational levels of (101) have been completely located up to  $J=6$ , together with many of the stronger, low  $\tau$ , levels of higher  $J$ , and of (200) up to  $J=5$ . These account for practically all the lines in the central region. At longer wave-lengths a number of weaker lines may be assigned to the perpendicular band (021), and a few to the parallel band (120), in agreement with the rotational analysis previously made from the solar absorption.<sup>2</sup> At the shortest wave-lengths there remain a few unassigned lines which undoubtedly belong to the second parallel band (002). A tentative analysis of the present data together with the photographic atmospheric absorption<sup>3</sup> locates most of the levels of this band up to  $J=3$ , giving  $\nu_0=7445.0\text{ cm}^{-1}$ , but further studies of the region from  $1.30\text{--}1.37\mu$  with long absorbing paths are required to confirm this identification.

In the  $1.9\mu$ -region the absorption is due almost entirely to the (011) band. With the aid of the weaker lines in the