Journal of Research of the National Bureau of Standards Vol. 49, No. 2, August 1952 Research Paper 2347

Absorption Spectrum of Water Vapor Between 4.5 and 13 Microns [1]

W. S. Benedict,[2] H. H. Claassen,[3] and J. H. Shaw [4]

The absorption spectrum of water vapor has been measured from 4.5 to 13 microns with a 3,600 line per inch replica echelette grating as the dispersing element. Various absorbing path lengths and concentrations of water vapor at atmospheric pressure were used up to 8 meters of steam near 110° C. Almost all of the previously unreported lines that have been found are also present in the solar spectrum. A rotational analysis shows that most of the lines can be assigned either to rotational transitions or to rotation-vibration transitions of the ν_2 fundamental of the water-vapor molecule. In addition, a few lines have also been assigned to the transitions $(2\nu_2-\nu_2)$, $(\nu_1-\nu_2)$, and $(\nu_3-\nu_2)$.

1. Introduction

Investigations of the infrared spectrum of sunlight between 7 and 13 μ have shown that essentially all the structure is due to absorption by polyatomic gases that are in the earth's atmosphere. In addition to the known bands of ozone, carbon dioxide, water vapor, nitrous oxide, and methane that have been identified in this region, there is also a large number of irregularly spaced absorption lines. Some of these lines are very strong. In solar spectra taken at Columbus, it has been observed that most of their intensities are dependent on the amount of water vapor in the atmosphere. One of us (W.S.B.) had previously found that many of these lines observed in the grating map of the solar spectrum published by Adel [1][5] could be predicted from the known energy levels of the water-vapor molecule. To obtain a positive identification of these lines, it was thought desirable to observe them in a laboratory spectrum. If these lines are due to water vapor, most of them must originate from the higher rotational energy levels of the molecule, which have a low population at room temperature. Thus, in order to observe them in the laboratory, an absorbing layer giving an optical path length approaching that of the water vapor in the atmosphere is required. In this work a long path length was obtained by using a multiple-reflection cell similar to that described by J. U. White [2]. From this laboratory spectrum it has been possible to identify many lines in the solar spectrum with water-vapor lines and also to evaluate rotational energy levels of the ν_2 band and of the pure-rotation band, which are in good agreement with levels derived from other observations.

2. Apparatus and Experimental Procedure

The absorption cell used in this investigation is shown schematically in figure 1. It consists of a large cast-aluminum tank wound with heating coils and covered with a layer of asbestos for insulation. One end is held in place by bolts and can be completely removed for adjusting the optical system. Three spherical mirrors, each of 100-cm radius of curvature, are used in the optical system. Mirror M_3 is fixed, but an external control is provided for varying the inclination of the optic axes of mirrors M_1 and M_2. By means of this adjustment the path length of radiation passing through the cell can be changed in steps of 4 m. Figure 1 shows the arrangement for a path length of 8 m.

Rocksalt windows could not be used in this investigation, and it was found that silver-chloride windows reduced the energy very considerably. Satisfactory results were obtained by placing the Nernst filament, used as a source, inside the cell near mirror M_3 and leaving the exit window open. Radiation was reflected out of the cell and through this window by a small plane mirror.

Before introducing the steam, the cell was heated to 110° C to prevent condensation on the mirrors. The cell was filled with steam by displacement. When running spectra, a continuous stream of vapor from a gently boiling flask of distilled water entered at one end and escaped through the exit window.

For mapping regions of high absorption, air was allowed to enter the cell until a suitable concentration of water vapor was obtained. Near the center of the ν_2 fundamental the atmospheric water vapor in the spectrometer alone was sufficient to produce very intense absorptions. The region from 5.7 to 6.7 μ has been previously mapped by H. H. Nielsen [3] with very high resolution and with small amounts of water vapor. The present workers were unable to improve upon these results, and this region has not been remeasured. In the solar spectrum no energy is observed between 5.5 and 7.5 μ at Columbus during most of the year.

The spectrometer with which these measurements were made has already been described [4]. For this work a 3,600 line/in replica echelette grating (width 5.5 in., height 3.5 in.) was used, together with a Perkin-Elmer thermocouple (rated sensitivity 8 v/w) detector and their 13 c/s chopping system and amplifier. All spectra were recorded in the first order of the grating. Portions of the spectrum at short wavelengths were also scanned in the second

[1] The research reported in this paper was supported in part by the ONR, and in part by contract AF 19 (122)-65 between the U. S. Air Force and the Ohio State University Research Foundation through sponsorship of the Geophysics Research Division of the U. S. Air Force Cambridge Research Center.

[2] Present address, The Johns Hopkins University, Baltimore, Md.
[3] Department of Physics, University of Oklahoma, Norman, Okla.
[4] The Ohio State University, Columbus, Ohio.

[5] Figures in brackets indicate the literature references at the end of this paper.

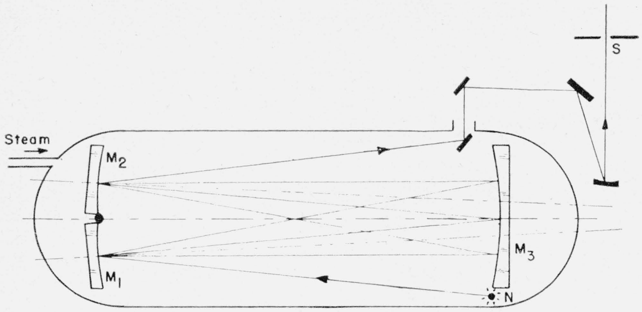

FIGURE 1. *Multiple reflection cell.*

order, but no improvement in the resolution was found.

After the spectrum of the 8-m path of water vapor had been obtained, the entire region was scanned by using the atmospheric path in the spectrometer alone. In this background spectrum, a line was found at 791 cm^{-1}, which agrees in position with the Q-branch of a band of carbon dioxide. It is very weak in the laboratory spectrum and is probably caused by the carbon dioxide in the air path of the spectrometer.

To obtain the spectrum, small portions, corresponding to the rotation through 1 deg of the grating circle, were scanned. The rocksalt foreprism was adjusted for maximum energy in the middle of each degree, which was then run at least twice in each direction. Fiduciary marks were made on the chart paper by a mechanical trigger device operated by an observer viewing coincidences of the grating circle markings with a graduated scale in the eyepiece of a microscope. The "central image" corresponding to the position of the grating for zero-order diffraction was measured during each day's work, in both directions. It was found to vary a few seconds of arc from day to day.

Frequencies were calculated by using the formula

$$\nu = nK/\sin\theta,$$

where n is the spectral order, ν the frequency, K is a constant, and θ is the angular displacement from the central image. K was determined from measurements of the 0.546073-, 0.576960-, and 0.579066-μ mercury lines in the orders from 10 to 16 using a low-pressure (H-2) mercury arc as a source and a 931A photomultiplier tube as detector. These measurements gave an average value for K of 722.506 ± 0.025 cm^{-1}.

The four or more frequency measurements obtained for each line, including scannings in both directions, were averaged. These frequencies were then corrected to vacuum by assuming the laboratory air had an average refractive index of 1.0002565, corresponding to a barometric pressure of about 740 mm Hg and a temperature of 25° C.

3. Results

A map of the water-vapor spectrum from 4.5 to 13 μ is shown in figures 2 to 6, with the exception of a short interval from 5.7 to 6.6 μ, where water-vapor absorption is very intense. To reach the longest wavelengths, the grating had to be used at extreme angles to the incident radiation, and very little energy was obtained even with the widest slits permissible. This accounts for the small deflection shown in figure 2 beyond 12 μ. As short portions of the spectrum were run individually, the total energy varied slightly, giving the segments shown in the figures. The approximate amounts of water vapor in the path for each region are given in the captions of the figures, as well as the temperature of the cell or spectrometer. It should be noted that when a temperature of 110° C is indicated, this refers to the temperature of the absorption cell. There was always some water vapor in the spectrograph at about 25° C, also contributing to the absorption. This contribution is quite negligible when the cell contains steam at atmospheric pressure. The regions near the center of the 6.3-μ band were run with only the air path in the spectrometer. Although spectra were recorded on a cold, dry day in February, many lines were still more intense than was desired.

The effective slit widths used varied from 0.22 cm^{-1} at 13 μ to 0.83 cm^{-1} at 5 μ. These slit widths were approximately the same as those used in the investigation of the solar spectrum. Under these conditions the lines in the laboratory spectrum were wider than corresponding lines in the solar spectrum. Consequently, some lines clearly separated in the solar spectrum are blended in the laboratory spectrum. The increased line width observed in the spectrum of steam is caused both by the higher temperature and the much higher concentration of water vapor, giving a marked self pressure broadening effect. Approximately the same deflections were obtained in windows between absorption lines whether the cell was full of steam or air, indicating that there was little continuous absorption by water vapor in these windows. Thus the wings of water-vapor lines lying outside the region investigated played an insignificant part in the absorption observed.

The lines have been numbered in order of increasing frequency in the figures as an aid to their identification in table 1. The line number is given in the first column of this table and the observed frequency, corrected to vacuum, in the second.

It is believed that the absolute values for the frequencies of well-defined lines are correct to better than 0.2 cm^{-1} at short wavelengths and to 0.1 cm^{-1} elsewhere. Most line frequencies have been given to 0.01 cm^{-1}, but some of the very weak lines that are difficult to measure accurately are listed to the nearest 0.1 cm^{-1}. A number of absorptions can be seen to consist of more than one line, and here the frequency of the position of the maximum absorption is listed to the nearest 0.1 cm^{-1}. Scattered radiation did not amount to more than 10 percent of the total deflection anywhere in the region measured and would not give rise to any spurious lines.

When the solar spectrum is compared with the laboratory spectrum, it is found that the relative intensities of some of the lines are very different.

This is to be expected because the amount of water vapor in the atmospheric path traversed by the solar radiation varies between 1,000 to 10,000 atm-cm and is at an average temperature of about 14° C, whereas the laboratory path was only 800 atm-cm but at a temperature of 110° C. The higher temperature of the laboratory sample gave intensities comparable with those in the solar spectrum to lines that originate from higher energy levels. However, lines arising from low-energy levels are little affected by the change in temperature from 14° to 110° C, and these lines were very weak or completely absent from the laboratory spectrum, although they may be quite prominent in the solar spectrum. This is illustrated by figures 7 and 8, which show small portions of the solar and laboratory spectra for comparison, together with the calculated spectra for the corresponding temperatures. The calculated spectra are schematically shown by drawing each line as a triangle, the width corresponding to geometric slit width used in the observed spectra, and the altitude proportional to the logarithm of the calculated intensity. The solar spectrum in figure 8 was observed during a cold winter day when the water-vapor content of the atmosphere was unusually low; so the calculated intensities for 14° C of table 1 were arbitrarily divided by 5 and plotted on the logarithmic scale indicated in the figure. Figure 7 also illustrates the greater line width of the laboratory steam spectrum than that of the solar spectrum.

In a number of cases where laboratory lines are very weak, or where several lines are blended, it is believed that more accurate frequencies can be obtained from the solar spectrum. Lines that appear in both spectra, but for which the frequencies from the solar spectrum have been used because they seem more reliable, are indicated by a dagger (†) in table 1. A few lines which appear only in the solar spectrum, but which can be fairly positively identified with water vapor because their intensities change with the amount of water vapor in the atmosphere or because they are theoretically predicted, have also been included in the table. Such lines have a dash in place of a line number.

The observed intensities of the lines are given in the next four columns. The first column gives the intensities of lines observed in the solar spectrum. A question mark in this column indicates that the intensity is uncertain because of absorption by other gases in the atmosphere. The values given are for "average" conditions of humidity and altitude of the sun. The intensity scale is very approximate, but runs from 0 to 100, corresponding roughly to percentage absorption at the maximum. The next three columns give intensities as observed under various laboratory conditions; first, when water in the spectrometer alone was sufficient; next, when steam was diluted to a small fraction of its maximum value; and finally, when the full path of 800 atm-cm was used. Figures 2 to 6 may be consulted for details. The steam was diluted over a wide range of concentrations so that the intensities for the diluted water vapor should be compared only for lines in the same neighborhood. In general, the absolute intensities of lines in the solar spectrum and the laboratory spectrum of the long path length of steam are roughly the same, although the intensities of the atmospheric lines vary considerably, depending on the altitude of the sun, the humidity, and the temperature of the atmosphere.

The sixth column of table 1 gives the identification of the line; or, if several transitions overlap to give an unresolved blend, the strongest components are listed. The identification consists of a letter symbol for the vibrational transition involved, the rotational quantum numbers of the upper state, J'_τ, and those of the lower state, J''_τ. The letter symbol a refers to pure-rotation transitions within the ground vibrational level. All identified lines with frequencies below 890 cm^{-1} are of this type, and they predominate up to 1,000 cm^{-1}. Near 1,000 cm^{-1} is a region of minimum absorption by water vapor. At lower frequencies the pure-rotation lines become stronger, and at higher frequencies those of the ν_2 band rapidly increase in intensity. The symbol b identifies transitions in the ν_2 fundamental. The remaining strong lines in the laboratory spectrum belong to this band. In addition, a few weak lines have been assigned to bands in which ν_2 is the lower state: c refers to the transition $2\nu_2-\nu_2$, d to $\nu_1-\nu_2$, and e to $\nu_3-\nu_2$.

The seventh column gives the calculated frequencies derived from the term values of the corresponding rotational states. These are listed for the three lowest levels in table 2, which has been compiled partly from the present research, and partly from an extensive reinvestigation of the complete water-vapor spectrum. The term values of the upper states of bands d and e have previously been given by Benedict and Plyler [5]. A calculated frequency in table 1 is the difference between two energy levels, J'_τ and J''_τ, involved in the transition. The calculated frequencies of a few lines have been placed in parentheses because in each case one of the levels concerned has been located by means of the observed line. These assignments depend on approximate predictions of the levels from extrapolations of regularities among the reliably known levels and on the agreement between calculated and observed intensities. For the remaining lines, however, other observed transitions connect the levels in question, and the agreement between observed and calculated frequencies is a true measure of the consistency of the measurements and the interpretation of the H_2O spectrum.

The final columns of table 1 list relative values of the calculated intensities, for temperatures of 14° and 110° C. These temperatures approximately correspond to the average temperature in the solar and laboratory spectra, respectively. The tabulated numbers are, for 14° C, $v(LS)ge^{-E''/kT}\cdot 10^6$, where (LS) is the line strength, as defined and tabulated by Cross, Hainer, and King [6], g is the statistical weight, and E'' is the energy of the lower state (from table 2). v is a numerical factor for the intensity of the vibrational transitions relative to the pure-rotation band, which will be discussed presently. The factor 10^6 was arbitrarily chosen so that medium-strength lines in the solar spectrum have intensities of the order of unity. For 110° C the factor was reduced to 10^5 to compensate for the increased Boltzmann factor.

For the pure-rotation band, it is possible to calculate intensities on an absolute basis, since all quantities in the theoretical formula

$$\int k_\nu d\nu = \frac{8\pi^3 N}{3hcQ} p^2 \nu.(LS) g e^{-E''/kT}$$

are known. $\int k_\nu d\nu$ is the integrated intensity of a line, N, h, c, and k are universal constants, Q is the state-sum, $\Sigma g e^{-E''/kT}$, and p is the static dipole moment, 1.86 Debye units. In order to convert our tabulated values for the pure-rotation band to the integrated intensity in units of $cm^{-2}atm^{-1}$, one must multiply by $2.19\times10^{-7}\times\nu(cm^{-1})$, at 287° K; at 383° K the factor is $1.07\times10^{-6}\times\nu(cm^{-1})$.

Not all of the transitions found in the course of this study are listed in the tables of reference [6]. The extension to $J\geq12$ requires a moderate extrapolation. Transitions in the $R_{5,\bar{5}}$ branch do not appear in their tables; according to a communication from Professor Cross, the line strength in nearly all these lines is less than 0.0001. For such lines the intensities have been estimated, and are placed in parentheses in table 1; the relative intensities at the two temperatures are significant, but the values may be in error by an order of magnitude.

The observed intensity of relatively weak lines in the pure rotation band, in both the solar and laboratory spectra, appear to be in fair agreement with the calculated absolute intensity. For example, the calculated intensity of line number one ($16_{-8}-15_{-10}$) is $\int I_\nu d\nu = 0.45\times2.19\times10^{-7}\times760 = 7.3\times 10^{-5}cm^{-2}atm^{-1}$. If the atmospheric path is 5×10^3 atm-cm, the equivalent width should be 0.36 cm^{-1}, which is of the same order as given by the observed maximum absorption of 45 percent, assuming that the line has a half-width 0.10 cm^{-1} and is observed with a slit width of 0.22 cm^{-1}. For the steam path of 800 atm-cm the calculated equivalent width of the same line becomes $1.6\times1.07\times10^{-6}\times760\times800=$ 1.04 cm^{-1}, again in order of magnitude agreement with the observed maximum absorption of 68 percent for a line of half-width 0.4 cm^{-1}.

For lines in ν_2, and in the upper-state bands, the absolute value of the theoretical intensity cannot be calculated, as it depends on the empirical factor v. The following values of v were chosen by which to multiply the pure-rotation intensities, in order to obtain fair over-all agreement with the observed intensities:

Band	$b(\nu_2)$	$c(2\nu_2-\nu_2)$	$d(\nu_1-\nu_2)$	$e(\nu_3-\nu_2)$
Factor	0.005	0.01	0.0002	0.001

These result in lines of the observed order of magnitude and are not unreasonable. The ν_2 intensities, calculated in this way, appear to be somewhat weaker than the observed intensities, in the region 900 to 1,050 cm^{-1}, and somewhat stronger than the observed intensities in the region 2,000 to 2,200 cm^{-1}, by a factor of 2 or 3 in each case. These effects, which may be in part due to the greater effective slit width in the short-wave region, are similar to those encountered in other bands of H_2O, and even more strikingly in H_2S and other asymmetric-top molecules. An explanation of these effects has recently been proposed by Nielsen [7]. The anomaly in ν_2 of H_2O does not appear outstandingly large in the portions of the P and R branches near the origin, but is confined to the transitions of high J and those in which K changes by more than 1.

4. Discussion

The agreement between the observed and calculated spectra as given in table 1, and illustrated in figures 7 and 8, is quite complete, and argues well both for the accuracy of the measurements and the correctness of the interpretation. The lines not accounted for constitute less than 1 percent of the total absorption intensity. A few of the assignments to transitions of highest J, in both the pure-rotation spectrum and in ν_2, are rather uncertain. It would be desirable to obtain further accurate measurements of steam in the region 550 to 770 cm^{-1} and of superheated steam or H_2-O_2 emission spectra throughout the rest of the vibration-rotation region, for confirmation. However, all the lower energy levels, up to $J=10$, are well accounted for, in that all predicted lines appear with approximately the correct intensity and frequency, and that no strong lines remain unidentified.

An additional demonstration that the spectral analysis is quite complete and essentially correct is afforded by the arrangement of the lines into series. Table 3 presents the lines of the four prominent P branches of the ν_2 vibration-rotation band, grouped in such a way as to display the regular decrease in frequency with increasing J. A similar array may be made for the lines in the R branches, as well as for the Q branch lines, most of which, however, lie in the central region not measured in this study. Frequencies in parentheses are those of weak lines overlapped by a stronger component. It is clear, by a comparison of tables 3 and 1, that the identification of many lines of higher J cannot be expected without an increase of the path length, or, preferably, by increasing the temperature. As mentioned before, there is a distinct difference in temperature coefficient between the weaker lines of the $P_{1,\bar{1}}$, $P_{\bar{1},\bar{1}}$, and $P_{\bar{1},1}$ branches, which have relatively high transition probabilities but originate from high-energy levels, and those of the $P_{\bar{3},1}$ branch (as well as the few identified lines of the $P_{\bar{3},3}$ branch, not included in table 3), which have lower line strengths but originate from lower energy levels. This difference manifests itself in the changed relative intensities in the laboratory and solar paths.

Table 4 is a similar presentation of the lines of the low-probability branches of the pure-rotation band.

For completeness, there are included lower lines of the series, as observed by other investigators [12, 13] in the farther infrared, as well as frequencies, in parentheses, of lines that have not yet been measured with high accuracy. A comparison with table 1 again shows that the suggested array accounts for most of the observed lines from 760 to 1,000 cm^{-1}, with the lines that are most enhanced in the atmosphere belonging, for the most part, to the more highly forbidden $R_{5,\bar{3}}$ and $R_{5,\bar{5}}$ series.

The energy levels of ν_2, which are now known with completeness and good precision up to $J=9$, permit an improved determination of the rotational constants for that vibrational level. The method is described elsewhere. Figure 9 presents the effective rotational constant A'_J, B'_J, and C'_J for each J, derived from the levels of table 2, plotted against $J(J+1)$. The points are seen to fall nicely on smooth curves. The intercepts give the rotational constants A, B, and C, and the limiting slopes give the centrifugal stretching constants D_A, D_B, and D_C. These are listed in table 5 and compared with the corresponding constants of the ground state. There is an appreciable curvature in the plot of A'_J, showing that centrifugal stretching terms of higher order are important at relatively low J.

The few weak lines that are not assigned may be transitions of higher J in ν_2, upper-state transitions, or lines in the isotopic molecules H_2O^{18} or HDO. The calculated vibrational shift for ν_2 of H_2O^{18} is -6.5 cm^{-1}; this shift would be increased for lines in the R branch and diminished in the P branch. Tentative assignments of some of the observed lines can be made on this basis; for example, line 285 (1414.99 cm^{-1}), which lies 4.3 cm^{-1} below the strong line 3_3-4_3, and line 353 (1764.22 cm^{-1}), which lies 8.4 cm^{-1} below the strong line 3_3-2_1, have the proper intensity ratio (1:500) and positions to be their analogues in H_2O^{18}. Other such possible lines are suggested in the table. It should be noted that, on the basis of the expected relative intensities, it would be very unlikely that many absorption lines due to HDO would appear. Although absorption due to the ν_2 band of this isotope has been postulated by Adel [8] in the 7.2 μ region of the solar spectrum, and the ν_1 fundamental has been definitely observed, resolved, and analyzed in the solar spectrum at 3.7 μ [9, 10], the intensity of the lines of the ν_2 fundamental of HDO relative to those of H_2O on our spectra would be very small. The frequencies of the ν_2 fundamental of HDO published by Barker and Sleator [11] do not show any definite coincidences with our data. There should, however, be a number of fairly strong lines at lower frequencies than their work reached, which would lie in the region of weaker H_2O absorption and might thus appear as weak lines in our spectra. For example, on the basis of the known structure of HDO, we calculate that the line 3_3-4_3 should fall near 1,250 cm^{-1}. Line 183, otherwise unaccounted for, has about the proper intensity in both laboratory and solar spectra for this transition.

It may also be of interest to point out that the completeness of the assignment, and the fact that the intensity differences in the spectra between atmospheric water vapor and nearly saturated steam can be explained in detail on the basis of temperature, is strong evidence, although of a negative sort, against the existence of $(H_2O)_2$ molecules in the saturated vapor. The association of H_2O in the liquid phase is abundantly proved by the marked lowering of frequency in the ν_3 fundamental and a somewhat smaller shift in ν_2. The existence of dimers in the vapor has often been postulated to account for changes in density, dielectric polarization, etc., near saturation. If such dimers exist as molecules with quantized vibration-rotation states, the evidence of the present study would be that their concentration, relative to H_2O monomer, must be less than 1 percent, since in the region of 1,400 cm^{-1}, where $(H_2O)_2$ should be most strongly absorbing, the unaccounted-for absorption is very small. We have mentioned previously that the steam spectrum shows a somewhat greater line width than the atmospheric spectrum, but there is no appreciable frequency shift, and the amount of self-broadening is by no means abnormally large for a polar molecule.

5. References

[1] A. Adel, Astrophys. J. **94,** 451 (1941).
[2] J. U. White, J. Opt. Soc. Am. **32,** 285 (1942).
[3] H. H. Nielsen, Phys. Rev. **59,** 565 (1941).
[4] J. H. Shaw, R. M. Chapman, J. N. Howard, and M. L. Oxholm, Astrophys. J. **113,** 268 (1951).
[5] W. S. Benedict and E. K. Plyler, J. Research NBS **46,** 246 (1951) RP2194.
[6] P. C. Cross, R. M. Hainer, and G. W. King, J. Chem. Phys. **12,** 210 (1944).
[7] H. H. Nielsen, Phys. Rev. **83,** 838 (1951).
[8] A. Adel, Astrophys. J. **93,** 509 (1941).
[9] R. M. Chapman and J. H. Shaw, Phys Rev. **78,** 71 (1950).
[10] W. Benesch, J. Strong, and W. S. Benedict, Progress Report to ONR, Contract N50ri–166 (Aug. 1, 1950).
[11] E. F. Barker and W. W. Sleator, J. Chem. Phys. **3,** 660 (1935).
[12] H. M. Randall, D. M. Dennison, N. Ginsburg, and L. R. Weber, Phys. Rev. **52,** 160 (1937).
[13] L. R. Weber and H. M. Randall, Phys. Rev. **40,** 835 (1932); C. S. Rupert, J. H. Taylor, and J. Strong, private communication.

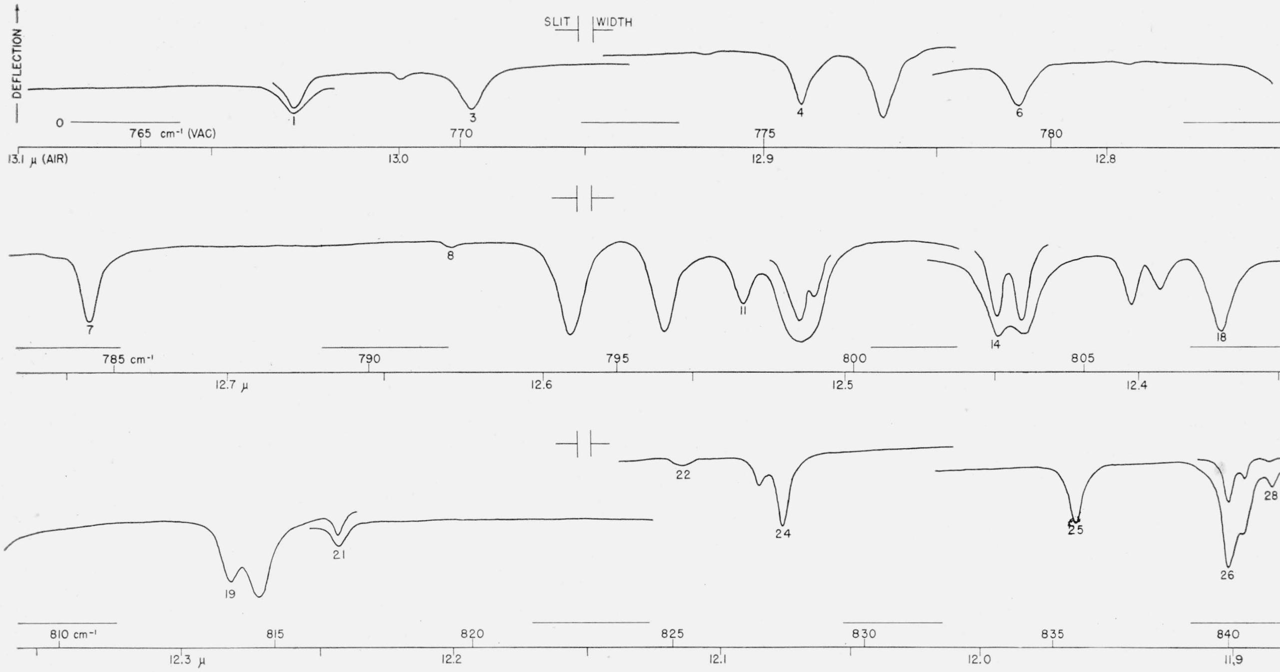

FIGURE 2. *Absorption spectrum from 11.9 to 13.1μ of an eight meter path of water vapor at 110°C and one atmosphere pressure.*

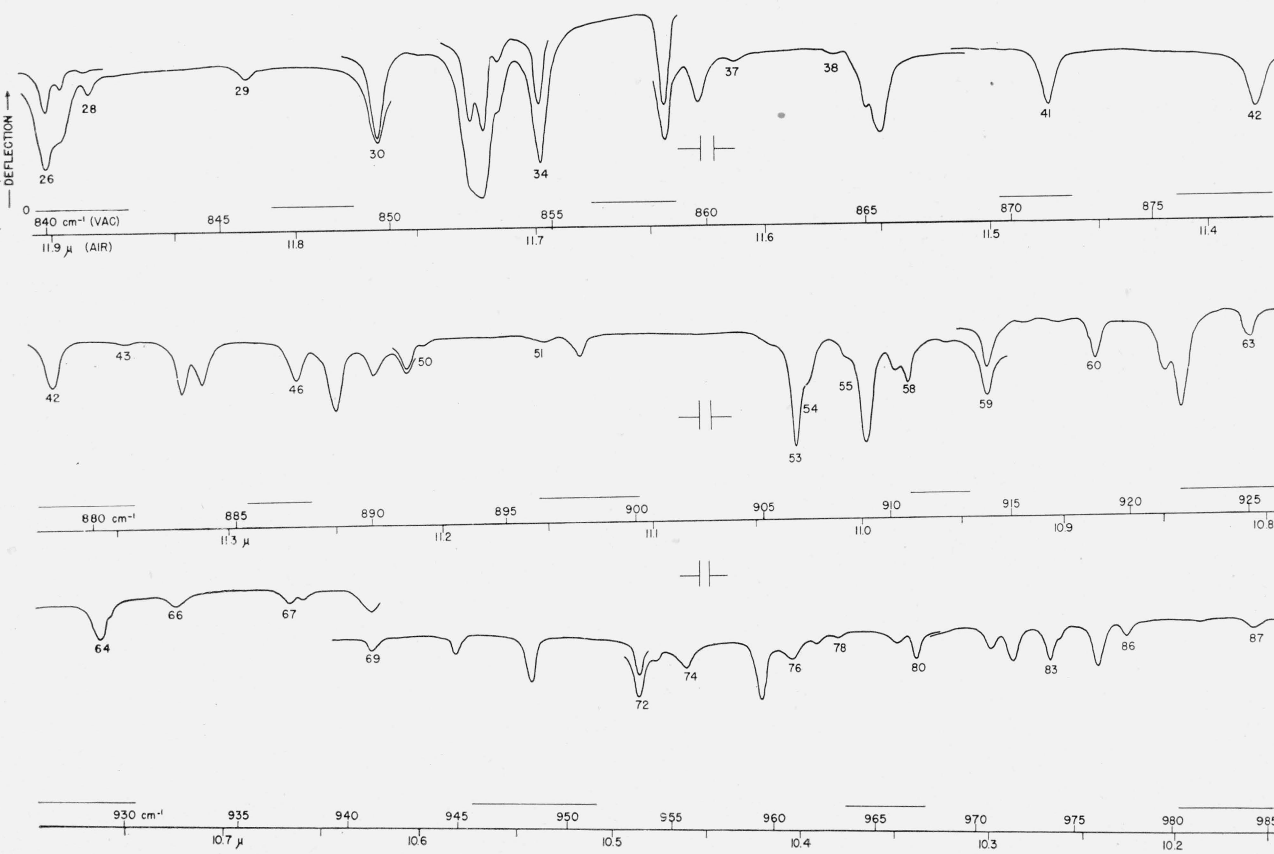

FIGURE 3. *Absorption spectrum from 10.2 to 11.9μ of an eight meter path of water vapor at 110°C and one atmosphere pressure.*

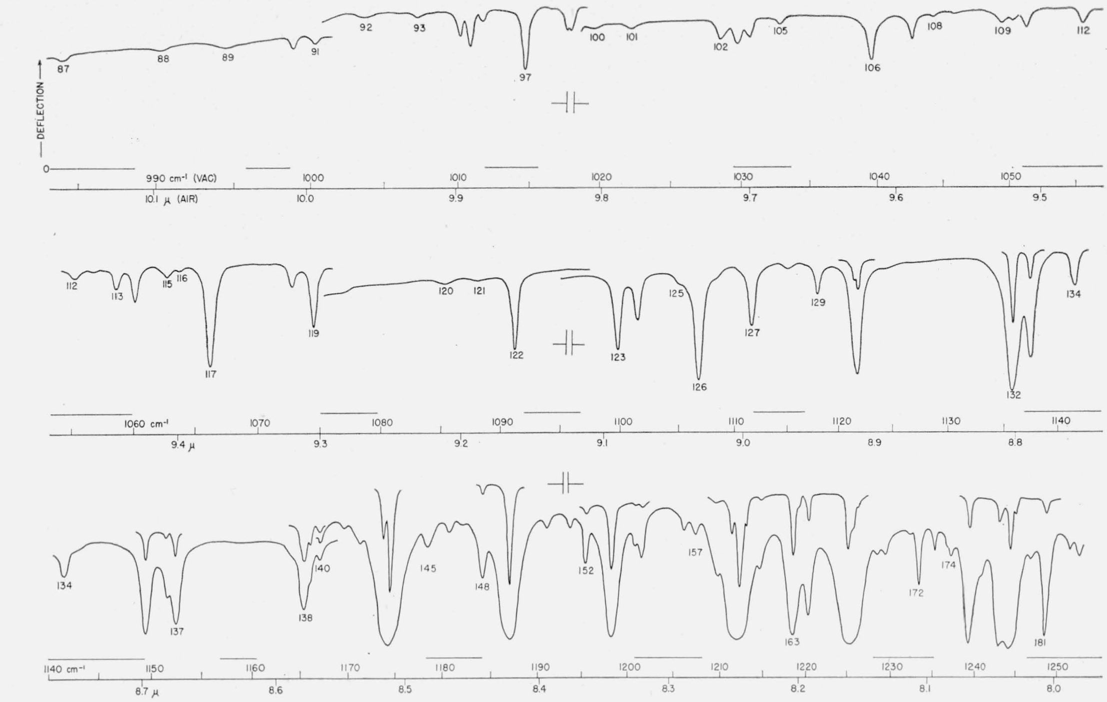

FIGURE 4. *Absorption spectrum from 10.2 to 11.9μ of an eight meter path of water vapor at 110°C and one atmosphere pressure and with small sections also at lower concentration.*

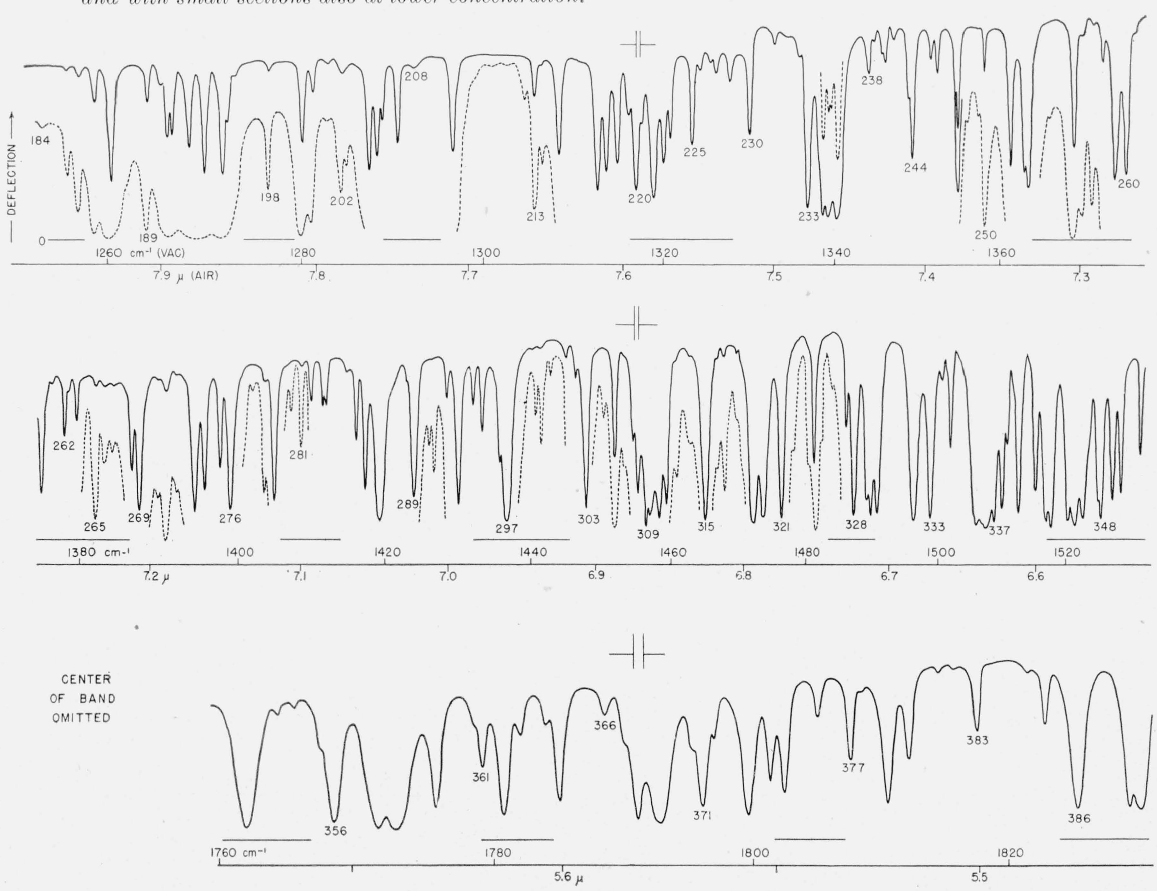

FIGURE 5. *Absorption spectrum from 5.5 to 5.7μ and from 6.6 to 8.0μ of water vapor.*

Solid line refers to water vapor in the air of the spectrometer at approximately 25°C, dotted line to an eight meter path at 110°C and various concentrations of water vapor in air.

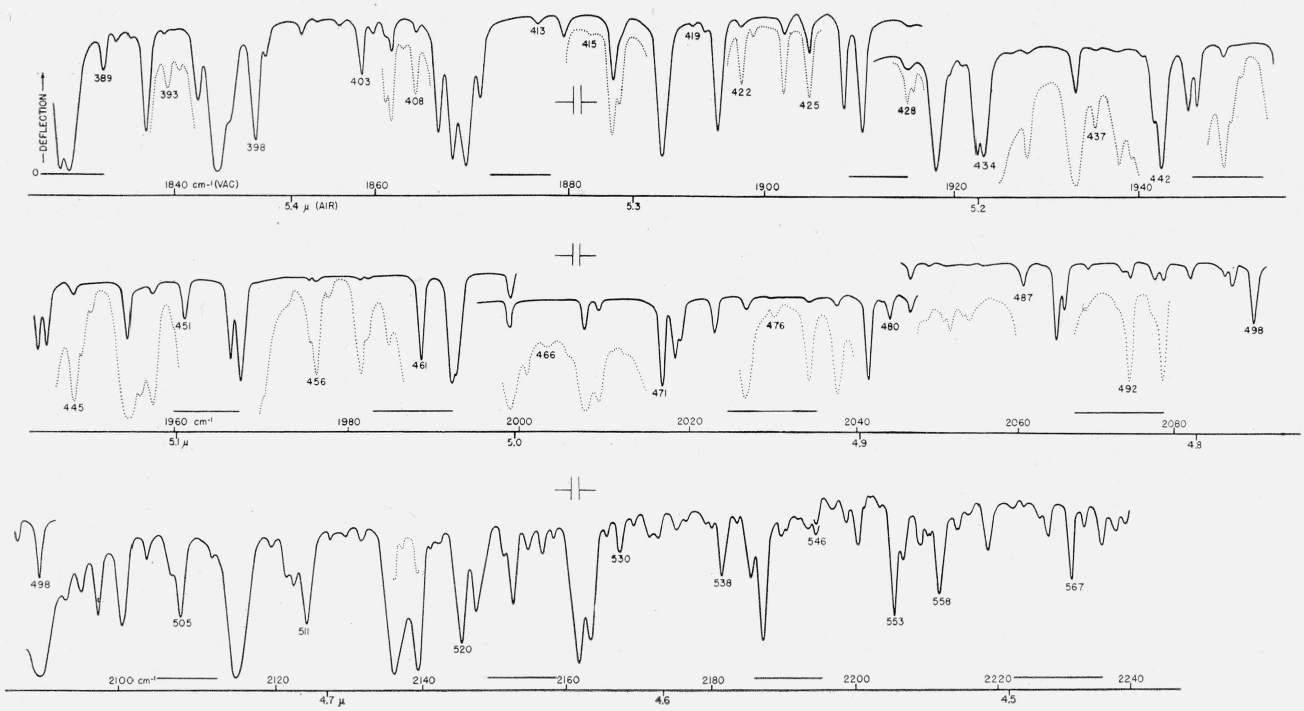

FIGURE 6. *Absorption spectrum from 4.5 to 5.5μ of water vapor.*

(A) Solid line refers to water vapor in spectrometer at approximately 25°C, dotted line to an eight meter path at 110°C and various concentrations of water vapor in air; (B) eight meter path at one atmosphere and 110°C.

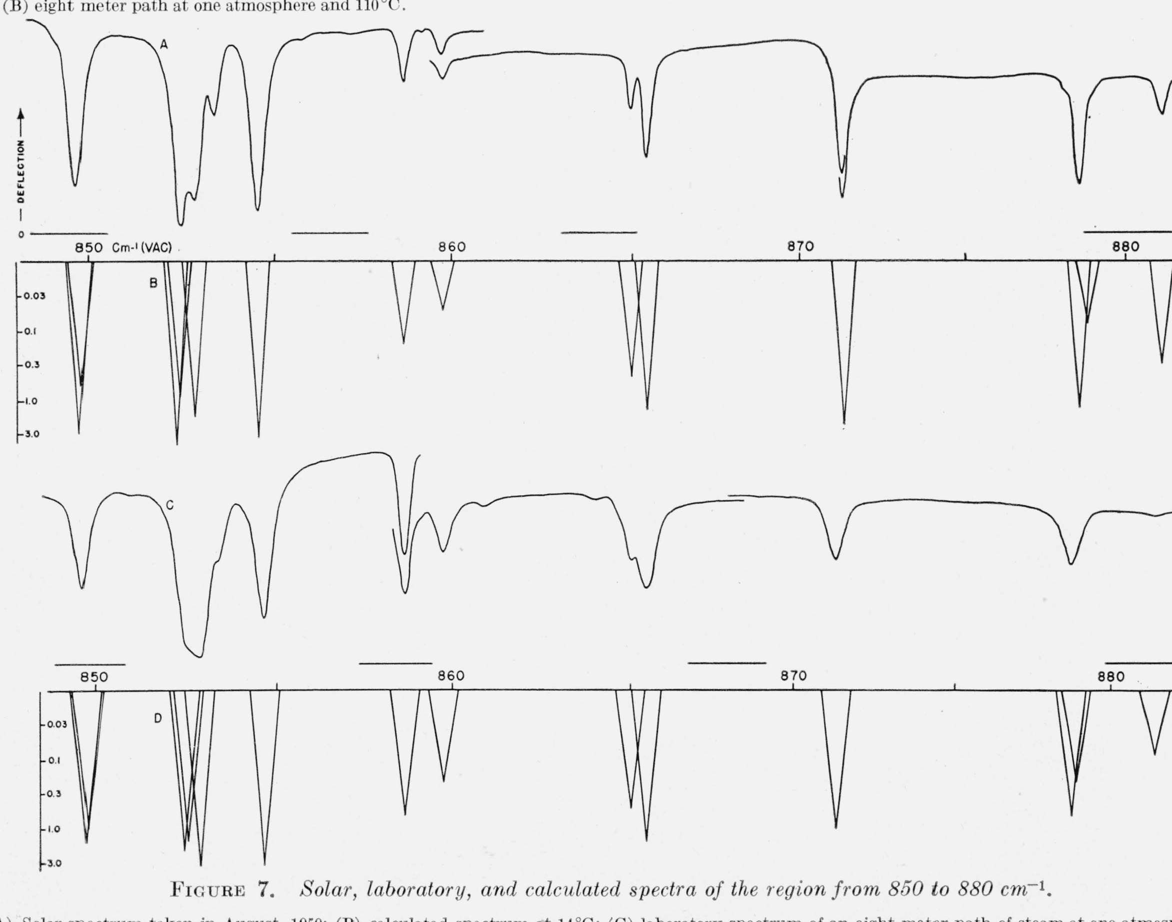

FIGURE 7. *Solar, laboratory, and calculated spectra of the region from 850 to 880 cm*$^{-1}$.

(A) Solar spectrum taken in August, 1950; (B) calculated spectrum at 14°C; (C) laboratory spectrum of an eight meter path of steam at one atmosphere and 110°C; (D) calculated spectrum at 110°C.

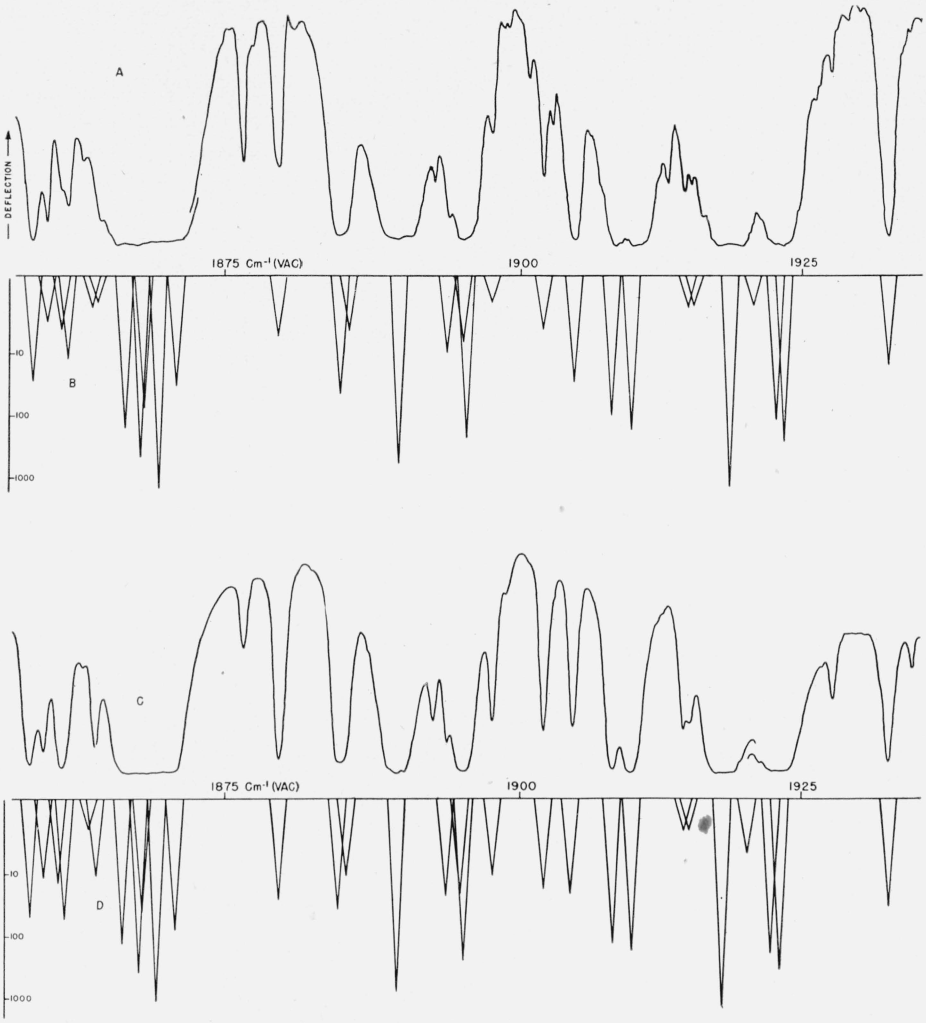

FIGURE 8. *Solar, laboratory and calculated spectra of the region from 1860 to 1925 cm^{-1}.*

(A) Solar spectrum taken in February 1951, with an air temperature of −15°C; (B) calculated spectrum at 14°C; (C) laboratory spectrum of a four meter path of steam at 110°C and nearly one atmosphere; (D) calculated spectrum at 110°C.

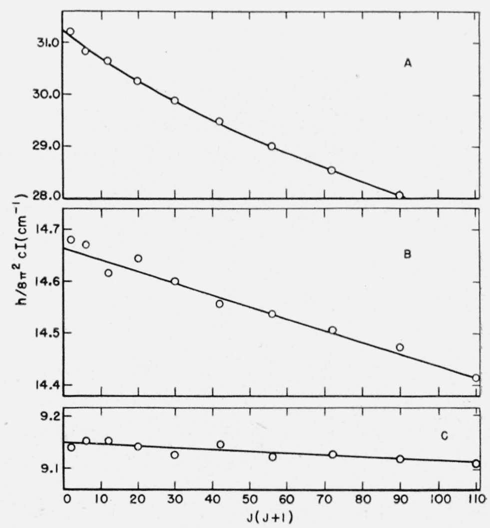

FIGURE 9. *Curves from which may be derived the inertial and centrifugal stretching constants associated with rotation about the three axes of inertia: (A) The least axis; (B) the intermediate axis; (C) the greater axis.*

TABLE 1. Absorption Spectrum of H_2O between 4.5μ and 13 μ.

Line Number	OBSERVED DATA						Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity					$J'_\tau - J''_\tau$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory								14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M							
1	767.37	45	0	-	68	a	16_{-8}	15_{-10}		(67.4)	0.44	1.6
2	769.1	50?	0	-	13	a	7_{5}	6_{-5}		69.15	(0.7?)	(0.12?)
3	770.17	60?	0	-	75	a	12_{2}	11_{-4}		70.17	3.6	3.5
4	775.63	30?	0	-	73	a	12_{-2}	11_{-8}		75.63	6.4	4.6
5	777.07	60?	0	-	94	a	10_{5}	9_{1}		77.09	11	7.5
6	779.36†	46	0	-	72	a	10_{6}	9_{0}		79.41	3.7	2.5
7	784.54	60?	0	-	73	a a	11_{-3} 16_{-7}	10_{-9} 15_{-11}		84.62 (84.54)	18 1.2	7.2 4.3
8[g]	791.6	-	5	-	5							
9	794.01	53?	0	-	89	a	13_{-1}	12_{-7}		94.01	6.4	8.0
10	796.01	85	0	-	88	a	10_{1}	9_{-7}		96.08	20	8.1
11	797.65	50	0	-	56	a	11_{4}	10_{0}		97.66	2.3	1.9
12	798.75	99	0	73	95	a	15_{-11}	14_{-13}		(98.75)	6.8	9.0
13	799.11	75	0	48	70	a a	10_{-1} 15_{-10}	9_{-9} 14_{-14}		99.16 (99.11)	25 2.2	7.7 3.0
14	803.09†	85	0	-	88	a	11_{5}	10_{-1}		03.10	6.7	5.5
15	803.60†	93	0	-	88	a	13_{1}	12_{-5}		03.61	3.1	5.2
16	806.06	30	0	-	54	a	16_{-10}	15_{-12}		(06.06)	0.3	0.75
17	806.75	10	0	-	36							
18	808.14† 808.33†	80 90	0	-	82	a a	16_{-9} 8_{5}	15_{-13} 7_{-3}		(08.14) 08.29	0.9 1.8	2.2 0.53
19	813.97	92	0	-	62	a	9_{9}	8_{3}		13.97	2.5	2.2
20	814.61	95	0	-	77	a	12_{3}	11_{-1}		14.60	3.4	4.1

See footnotes at end of table.

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity					J'_τ —	J''_τ	Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory								
			Air only	110° C (8 Atmo-M)	110° C 8 Atmo-M					14° C	110° C
21	816.55	10	0	-	20						
22	825.24†	85	0	-	5	a	8_{4}	7_{-6}	25.16	1.0 ?	0.4 ?
23	827.21	50	0	-	18	a	13_{2}	12_{-2}	27.31	0.42	0.73
24	827.80	95	0	-	42	a a	12_{4} 9_{4}	11_{-2} 8_{-4}	27.86 27.67	0.45 1.4	0.57 0.47
25	835.64	32	0	-	36	a a	14_{1} 17_{-9}	13_{-3} 16_{-11}	35.64 (35.64)	0.30 0.10	0.78 0.55
26	840.01	90	0	-	66	a a	10_{7} 10_{8}	9_{3} 9_{2}	40.01 40.15	1.6 0.53	1.7 0.56
27	840.36†	45	0	-	46	a	14_{0}	13_{-6}	(40.36)	0.24	0.50
28	841.16	5	0	-	13	a	15_{0}	14_{-4}	(41.16)	0.016	0.065
-	841.97†	26	0	-	0	a	7_{7}	6_{-3}	41.93	(0.2)	(0.04)
29	845.83	3	0	-	9						
30	849.69	78	0		56	a	11_{0}	10_{-8}	49.79	2.9	1.6
31	852.62	99	0	50	92	a a	10_{3} 13_{3}	9_{-5} 12_{-3}	52.51 52.60	4.3 0.88	2.0 1.5
32	852.91	86	0	59	96	a	16_{-11}	15_{-15}	(52.92)	1.7	3.4
33	853.41	40	0	12	40	a	14_{-2}	13_{-8}	53.41	0.59	1.0
34	854.66	92	0	40	75	a	13_{-3}	12_{-9}	54.66	3.5	3.3
35	858.65	27	0	-	49	a	17_{-11}	16_{-13}	(58.65)	0.15	0.64
36	859.78	9	0	-	29	a	17_{-10}	16_{-14}	(59.78)	0.05	0.21
37	861.0	-	0	-	4						
38	864.0	-	0	-	3						
39	865.02†	32	0	-	37	a	11_{6}	10_{2}	65.01	0.46	0.49
40	865.51†	58	0	-	54	a	11_{7}	10_{1}	65.49	1.4	1.5

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				$J'_\tau - J''_\tau$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
41	871.32†	78	0	-	36	a	11_{-2}	10_{-10}	71.49	2.3	0.92
42	878.61†	68	0	-	36	a a	12_{-4} 14_{2}	11_{-10} 13_{-4}	78.70 78.9	1.3 0.08	0.65 0.20
43	881.15†	23	0	-	2	a	8_{6}	7_{-4}	81.20	(0.3)	(0.08)
44	883.18	24	0	-	32	a	15_{-1}	14_{-7}	(83.18)	0.13	0.18
45	883.89	59	0	-	25	a	11_{2}	10_{-6}	84.01	0.95	0.57
46	887.33	72	0	-	22	a	9_{3}	8_{-7}	87.44	(1.1)	(0.27)
47	888.71	46	0	-	41	a	12_{5}	11_{1}	88.71	0.63	0.90
48	890.14	26	0	-	16	a	12_{6}	11_{0}	90.16	0.21	0.30
49	891.33	41	0	-	17	a	10_{9}	9_{5}	91.33	0.28	0.26
50	892.1†	6	0	-	4						
51	896.57†	10	0	-	4	b	12_{-12}	13_{-8}	96.53	0.006	0.009
52	897.77†	22	0	-	14	b	12_{-11}	13_{-9}	97.77	0.017	0.027
-	905.50†	10	0	-	0	b	10_{-7}	11_{-1}	05.34	0.012	0.014
53	906.32	56	0	-	69	a	17_{-13}	16_{-15}	(06.32)	0.3	0.8
54	906.8	13	0	-	30	a	15_{1}	14_{-5}	(06.6)	0.06	0.09
55	908.09†	15	0	-	12						
56	909.02	83	0	-	67	a	12_{-1}	11_{-9}	09.12	3.0	2.0
57	910.17	20	0	-	21	a	13_{4}	12_{0}	10.4	0.08	0.17
58	910.77	12	0	-	27	a	18_{-11}	17_{-15}	(10.8)	0.02	0.12
59	914.06	34	0	-	33	a	13_{5}	12_{-1}	14.06	0.24	0.50
60	918.52	37	0	-	23	a	11_{9}	10_{3}	18.52	0.25	0.31

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				J'_τ — J''_τ			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
61	921.48†	35	0	-	31	a	15_{-3}	14_{-9}	(21.48)	0.29	0.70
62	922.19†	89	0	-	52	a	12_{1}	11_{-7}	22.41	1.5	1.2
63	925.05†	80	0	-	15	a	9_{5}	8_{-5}	25.12	(1.0)	(0.3)
64	929.00	22	0	-	18	a	14_{3}	13_{-1}	29.00	0.063	0.20
65	929.4	0	0	-	6						
66	932.32	1	0	-	5						
67	937.40	5	0	-	6	a	14_{4}	13_{-2}	37.2	0.020	0.06
68	938.2	2	0	-	4						
69	941.12	20	0	-	8	a	14_{-4}	13_{-10}	(41.1)	0.29	0.36
70	944.95	13	0	-	11	b a	9_{-1} 12_{7}	10_{3} 11_{3}	44.90 44.96	0.022 0.22	0.029 0.35
-	946.73†	6	0	-	0	a	8_{7}	7_{-1}	46.73	0.13	0.04
71	948.35	66	0	-	27	a	12_{-3}	11_{-11}	48.40	1.9	1.0
72	953.49	30	0	-	25	b	11_{-11}	12_{-7}	53.49	0.069	0.078
73	954.17†	7	0	-	6	b	8_{-1}	9_{5}	53.99	0.014	0.013
-	955.33†	24	0	-	0	a	10_{2}	9_{-8}	55.50	(0.3)	(0.09)
74	955.71	9	0	-	13	b	11_{-10}	12_{-8}	55.71	0.023	0.026
75	959.33	10	0	-	36	a a	18_{-13} 9_{6}	17_{-17} 8_{-2}	(59.33) 59.79	0.05 (0.05)	0.21 (0.02)
76	960.5† 961.1†	5 4	0	-	12	a b	15_{3} 8_{0}	14_{-3} 9_{4}	(60.5) 60.91	0.003 0.005	0.014 0.005
77	962.05	-	0	-	5	a	11_{11}	10_{5}	62.1	0.025	0.04
78	963.0	-	0	-	3						
79	966.01	11	0	-	7	b	9_{-6}	10_{0}	65.93	0.019	0.016
80	967.00	15	0	-	16	a	13_{0}	12_{-8}	(67.00)	0.20	0.22

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				$J'_\tau — J''_\tau$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
81	970.66	10	0	-	8	a	13_{6}	12_{2}	70.52	0.016	0.04
						a	13_{7}	12_{1}	70.75	0.047	0.12
-	971.43†	18	0	-	0	a	10_{5}	9_{-3}	71.53	0.20	0.10
82	971.75	12	0	-	20						
83	973.59	15	0	-	19	a	13_{-2}	12_{-10}	73.65	0.33	0.30
84	974.04†	16	0	-	7	a	10_{4}	9_{-6}	74.04	0.5	0.19
85	976.07	40	0	-	24	a	13_{-5}	12_{-11}	76.07	0.7	0.5
86	977.54	15	0	-	8	b	8_{-7}	9_{-1}	77.28	0.084	0.045
87	984.2	5	0	-	5	a	11_{4}	10_{-4}	84.15	0.14	0.10
88	990.3	6	0	-	3	a	12_{9}	11_{5}	(90.3)	0.007	0.015
89	994.4	10	0	-	4						
90	998.87	30?	0	-	10	b	8_{-3}	9_{3}	98.70	0.080	0.026
91	1000.35	25?	0	-	6	a	12_{3}	11_{-5}	00.47	0.20	0.19
92	1003.8	10?	0	-	3	a	9_{7}	8_{-3}	03.85	(0.40)	(0.14)
93	1007.3	15?	0	-	4	b	11_{-5}	12_{-1}	07.08	0.017	0.035
94	1010.12	15?	0	-	16	b	10_{-10}	11_{-6}	09.96	0.11	0.085
95	1010.86	15?	0	-	22	b	11_{-9}	12_{-5}	11.06	0.10	0.143
96	1011.64	10?	0	-	7						
97	1014.56	50?	0	-	38	b	10_{-9}	11_{-7}	14.38	0.318	0.265
98	1017.6	20?	0	-	15	b	8_{-5}	9_{1}	17.79	0.202	0.128
99	1017.9	30?	0	-	17	a	14_{-1}	13_{-9}	(17.9)	0.16	0.22
100	1019.5	5?	0	-	2	b	10_{-4}	11_{0}	19.52	0.013	0.018

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				$J'_{\tau} - J''_{\tau}$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
101	1022.0	5?	0	-	4	a	13_{2}	12_{-6}	21.55	0.053	0.078
102	1028.47	30?	0	-	13	b a	7_{-2} 11_{3}	8_{4} 10_{-7}	28.47 28.45	0.043 0.5	0.024 0.25
103	1029.69	20?	0	-	17	b a	9_{-3} 11_{1}	10_{1} 10_{-9}	29.58 29.87	0.084 1.14	0.082 0.45
104	1030.58	10?	0	-	13	b	11_{-8}	12_{-6}	30.0	0.033	0.048
105	1032.76	20?	0	-	5						
106	1039.53	?	0	-	30	b b	8_{-2} 11_{-7}	9_{2} 12_{-3}	39.31 39.35	0.043 0.075	0.034 0.128
107	1042.57	15?	0	-	17	a	14_{-3}	13_{-11}	(42.5)	0.22	0.28
108	1044.4	?	0	-	3						
109	1049.39	?	0	-	7	b	7_{-6}	8_{0}	49.39	0.13	0.052
110	1050.22	?	0	-	6						
111	1051.28	?	0	-	11	b	7_{-1}	8_{3}	51.28	0.176	0.096
112	1055.56	20?	0	-	8	b	6_{-1}	7_{5}	55.21	0.164	0.075
113	1058.69	?	0	-	13	b	12_{-7}	13_{-5}	58.57	0.028	0.065
114	1060.14	?	0	-	23	b	10_{-8}	11_{-4}	60.06	0.146	0.146
115	1062.61	?	0	-	8	b	7_{-4}	8_{2}	62.50	0.154	0.075
116	1063.6	?	0	-	3						
117	1066.20	85?	0	-	70	b b	9_{-9} 6_{0}	10_{-5} 7_{4}	66.14 66.17	1.17 0.057	0.71 0.025
118	1072.69	?	0	-	15	b	10_{-6}	11_{-2}	72.52	0.084	0.10
119	1074.46	70?	0	-	41	b	9_{-8}	10_{-6}	74.31	0.415	0.25
120	1085.4	?	0	-	3	b	5_{1}	6_{5}	85.37	0.096	0.035

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
121	1088.1	?	0	-	2						
122	1091.24	82	0	-	55	b	10_{-7}	11_{-5}	91.21	0.575	0.54
123	1099.74	72	0	-	54	b	9_{-5}	10_{-1}	99.04	0.665	0.55
124	1101.47	76	0	-	34	b	6_{-3}	7_{3}	01.42	0.85	0.32
125	1105.3	5?	0	-	8						
126	1106.76	83	0	-	78	b	9_{-7}	10_{-3}	06.73	1.60	1.15
127	1111.59	82	0	-	41	b	6_{-5}	7_{1}	11.50	1.21	0.41
128	1114.8	?	0	-	4	c	7_{-5}	8_{-1}	14.30	0.010	0.03
129	1117.71	23?	0	-	19	b	11_{-6}	12_{-4}	17.60	0.063	0.098
130	1120.9	84	0	14 }	76	b	8_{-4}	9_{0}	20.76	0.45	0.29
131	1121.24	89	0	21 }		b	8_{-8}	9_{-4}	21.24	1.37	0.62
132	1135.80	98	0	44	86	b	8_{-7}	9_{-5}	35.80	1.78	0.80
133	1137.46	85	0	16	65	b	7_{-3}	8_{1}	37.19	1.63	0.78
134	1141.64	22?	0	-	23	b	12_{-5}	13_{-3}	41.59	0.034	0.088
135	1149.48	77	0	22	78	b	8_{-6}	9_{-2}	49.39	1.82	0.98
136	1151.59	70	0	5	47	b	6_{-2}	7_{2}	51.55	0.66	0.25
137	1152.44	77	0	19	72	b	9_{-6}	10_{-4}	52.42	0.91	0.63
138	1165.27†	87	0	29	59	b	5_{-4}	6_{2}	65.10	0.86	0.22
139	1165.4† 1165.9	83 } 73 }	0	15	35	b b	5_{-1} 4_{-1}	6_{3} 5_{5}	65.40 65.84	1.56 0.59	0.48 0.145
140	1167.04	?	0	5	16	c c	8-5 5_{-3}	9_{-3} 6_{1}	66.8 67.1	0.009 0.014	0.032 0.030

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_{τ}	J''_{τ}	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
141	1169.4	?	0	-	4						
142	1171.4	?	0	-	11	b	9_{-8}	9_{-2}	71.47	0.043	0.021
143	1173.76	99 (143–144)	0	33	99 (143–144)	b	10_{-5}	11_{-3}	73.74	1.11	1.09
144	1174.54		0	68		b	7_{-7}	8_{-3}	74.54	12.6	4.4
145	1178.55	15?	0	-	15						
146	1180.75	55?	0	-	9	b	4_{0}	5_{4}	80.94	0.29	0.06
147	1182.2	?	0	-	3						
148	1184.14	?	0	6	44	b	12_{-3}	13_{-1}	83.95	0.068	0.206
149	1187.00	99	0	70	98	b b	11_{-4} 7_{-5}	12_{-2} 8_{-1}	86.65 87.11	0.105 11.4	0.189 4.7
150	1191.16	35?	0	-	9						
151	1193.67	28?	0	-	9						
152	1195.41	?	0	6	27	b	12_{-1}	13_{1}	95.28	0.046	0.196
153	1198.22	98	0	48	95	b	7_{-6}	8_{-4}	98.18	5.2	1.78
154	1200.80	?	0	2	17						
155	1201.55	?	0	4	30	b b	12_{1} 12_{2}	13_{3} 13_{2}	01.58 01.8	0.021	0.099
156	1206.07† 1206.37†	52? 30?	0	-	13						
157	1207.35	?	0	-	13	c	5_{-5}	6_{-1}	07.5	0.048	0.082
158	1209.79	?	0	3	46	c b	6_{-5} 12_{3}	7_{-3} 13_{5}	09.6 09.7	0.036 0.007	0.072 0.047
159	1211.29	99	0	23	99 (159–160)	b	4_{-3}	5_{3}	11.29	3.4	0.73
160	1212.28	99	0	60		b	8_{-5}	9_{-3}	12.23	12.8	6.4

TABLE 1— Continued.

Line Number	OBSERVED DATA: Wave Number cm^{-1} (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm^{-1} (vac)	Intensity: 14° C	Intensity: 110° C
161	1213.0	?	0	19	99	b	11_{-2}	12_{0}	13.00	0.10	0.22
162	1214.91	?	0	3	25	b	8_{-7}	8_{-1}	15.06	0.36	0.15
163	1218.63	98	0	40	90	b	6_{-4}	7_{0}	18.63	6.70	2.07
164	1219.1	?	0	9		b	11_{0}	12_{2}	19.2	0.060	0.16
165	1220.43	?	0	18	70	b	11_{1}	12_{1}	20.60	0.18	0.47
						b	11_{3}	12_{3}	24.76	0.10	0.34
166	1225.08	99	0	38	99	b	6_{-6}	7_{-2}	25.08	11.0	3.08
						b	9_{-4}	10_{-2}	25.08	2.05	1.56
167	1225.5	99	0	25		b	10_{-3}	11_{-1}	25.46	1.97	2.36
168	1226.1	78?	0	9		b	11_{-1}	12_{-1}	26.06	0.355	0.74
169	1228.53	?	0	-	13						
170	1229.43	?	0	-	14	b	9_{-9}	9_{-3}	29.35	0.80	0.40
171	1232.1	?	0	-	3						
172	1233.31	?	0	-	47	b	11_{5}	12_{5}	32.88	0.041	0.18
173	1235.23	?	0	-	19						
174	1237.20	?	0	-	19	b	11_{-9}	11_{-3}	36.7	0.056	0.061
						b	6_{0}	6_{-6}	37.41	0.021	0.008
175	1239.25	?	0	25	98	b	10_{-1}	11_{1}	39.19	1.50	2.17
176	1240.6	?	0	-	35						
177	1242.90	95?	0	17	98	b	10_{1}	11_{3}	42.75	1.17	2.11
						b	10_{2}	11_{2}	43.1	0.39	0.70
178	1244.18	99	0	40	99	b	5_{-3}	6_{1}	44.04	24.1	6.27
179	1244.77		0	11		b	10_{0}	11_{0}	44.66	0.52	0.99
180	1246.63	?	-	0	7	b	7_{-1}	7_{5}	46.48	0.14	0.06

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_{τ}	J''_{τ}	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
181	1248.52	?	-	11	86	b	10_{3}	11_{5}	48.49	0.46	1.06
182	1251.43	?	-	-	13	b	3_{-2}	4_{4}	51.46	0.74	0.14
183	1252.44	?	-	-	17						
184	1253.67	?	-	0	5	b	7_{-6}	7_{0}	53.51	0.43	0.14
185	1255.95	?	-	3	40	b	16_{-15}	17_{-17}	(56.0)	0.095	0.40
186	1257.07	?	-	6	67	b b	10_{5} 11_{-3}	11_{7} 12_{-3}	57.07 57.10	0.182 0.645	0.56 1.10
187	1258.63	95	-	21	91	b	9_{-2}	10_{0}	58.63	3.1	2.7
188	1260.38	99	-	67	99	b	6_{-5}	7_{-3}	60.32	53.7	14.5
189	1264.04	?	-	22	92	b	9_{0}	10_{2}	63.93	2.0	2.1
190	1265.42	?	-	12		b	4_{-2}	5_{2}	65.30	5.5	1.15
191	1266.11	?	-	41		b	9_{1}	10_{1}	66.31	6.2	6.5
192	1266.63	?	-	39		b	9_{3}	10_{3}	66.55	4.2	4.5
193	1268.40	99	-	49	} 99	b b b	10_{-2} 10_{7} 7_{-4}	11_{-2} 11_{9} 8_{-2}	67.83 67.93 68.28	0.90 0.06 19.2	1.02 0.26 7.1
194	1269.97	99	-	60		b	8_{-3}	9_{-1}	69.72	31.1	17.0
195	1271.80	99	-	61		b	5_{-5}	6_{-1}	71.73	73	16.3
196	1272.37	?	-	31		b	9_{5}	10_{5}	72.22	1.80	2.90
197	1273.1	80?	-	6		b b	6_{-3} 9_{-3}	6_{3} 9_{3}	72.64 73.24	0.78 0.14	0.23 0.10
198	1276.63	?	-	6	65	b	15_{-15}	16_{-15}	76.67	0.50	1.35
199	1280.09	99	-	48	99	b	9_{-1}	10_{-1}	80.09	10.4	8.88
200	1281.22	85?	-	20	89	b	9_{7}	10_{7}	80.99	1.06	2.30

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
201	1282.9	?	-	3	7						
202	1284.37	?	-	10	63	b	3_{-1}	4_3	84.14	5.9	1.09
203	1284.89	?	-	0	40						
204	1287.38		-	61		b	8_{-1}	9_1	87.29	33.9	21.7
205	1288.28	99	-	55	99	b	8_1	9_3	88.18	21.4	16.5
206	1288.92		-	33		b	8_2	9_2	88.82	7.15	5.50
207	1290.59	?	-	47	98	b	8_3	9_5	90.52	14.6	18.2
208	1292.40	?	-	6	75	c b	6_3 9_9	7_5 10_9	92.0 92.30	0.10 0.25	0.05 0.69
209	1296.67	?	-	55	99	b b	8_5 8_0	9_7 9_0	96.59 96.53	6.25 12.1	7.81 7.6
210	1300.9	?	-	0	2	c	6_5	7_7	01.0	0.04	0.19
211	1302.7	?	-	0	2						
212	1304.46	?	-	0	22						
213	1305.60	?	-	23	89	b	8_7	9_9	05.49	2.48	3.09
214	1306.31	?	-	5	54						
215	1308.25	?	-	55	96	b	7_{-2}	8_0	08.18	42.0	17.4
216	1312.61	?	-	75	-	b	7_3	8_3	12.71	88	52
217	1313.64	?	-	64	-	b b	4_{-4} 7_0	5_0 8_2	13.35 13.68	39 36.7	7.4 17.6
218	1314.82	?	-	59	-	b	7_5	8_5	14.73	43.8	31.9
219	1316.20	?	-	32	-	b	11_{-5}	12_{-5}	16.38	1.67	2.39
220	1317.04	?	-	75	-	b	7_1	8_1	16.92	113	54

TABLE 1 — Continued.

Line Number	Observed Data: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (<8 Atmo-M)	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	Calculated Data: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
221	1317.6		-	37	-	b	13_{-13}	14_{-13}	17.65	8.15	10.9
222	1318.97		-	77	-	b b	6_{-3} 10_{-4}	7_{-1} 11_{-4}	18.95 19.21	211 2.0	61 2.0
223	1320.09		-	58	-	b	5_{-4}	6_{-2}	20.13	61.4	13.3
224	1320.90		-	44	-	b	7_{7}	8_{7}	20.93	19.2	18.0
225	1323.31		-	51	-	b	9_{-3}	10_{-3}	23.29	19.5	14.2
226	1324.30		-	10	-	c	5_{1}	6_{1}	24.2	0.53	1.07
227	1325.63		-	8	-						
228	1326.14		-	14	-	b b	13_{-11} 13_{-9}	14_{-11} 14_{-9}	26.08 26.4	1.93 0.50	3.48 1.20
229	1327.72		-	22	-	b	9_{-7}	9_{-1}	27.70	2.50	1.37
230	1329.90		-	52	-	b	8_{-2}	9_{-2}	29.72	19.3	10.4
231	1332.70	Complete Absorption	-	8	-	b	7_{-3}	7_{3}	32.49	0.78	0.30
232	1335.55		-	14	-						
233	1336.64		-	88	-	b	6_{3}	7_{5}	36.56	239	110
234	1338.56		55	92	-	b b	12_{-11} 6_{1}	13_{-13} 7_{3}	37.83 38.50	28.6 308	27.5 117
235	1339.23		40	93	-	b	6_{5}	7_{7}	39.39	117.5	68.1
236	1339.55		39		-	b	6_{2}	7_{2}	39.59	103	39
237	1340.35		67	95	-	b b	7_{-1} 6_{-1}	8_{-1} 7_{1}	40.09 40.37	169 364	69 118
238	1344.04		-	22	-	b	12_{-9}	13_{-11}	44.0	7.4	9.5
239	1344.60		-	7	-						
240	1345.59		-	13	-	b	12_{-7}	13_{-9}	45.7	1.55	2.60

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (8 Atmo-M)	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
241	1345.97	↑ Complete Absorption ↓	-	18	-	c	4_1	5_3	46.0	1.22	2.04
242	1347.01		-	6	-	c	4_2	5_2	47.1	0.41	0.68
243	1349.0		-	34	-						
244	1349.39		-	64	-	b	3_{-3}	4_1	49.43	113	18.4
245	1351.67		-	15	-						
246	1352.41		-	21	-	b	11_{-7}	12_{-7}	52.4	5.65	6.61
247	1354.87		-	80	-	b	6_0	7_0	54.80	164	53
248	1356.0		-	13	-	c b	5_{-1} 8_{-6}	6_{-1} 8_0	55.4 56.54	0.86 2.6	1.47 1.08
249	1357.21		-	13	-						
250	1358.06		-	55	-	b	11_{-11}	12_{-11}	58.02	91	65
251	1361.09		70	-	-	b b	11_{-9} 5_5	12_{-9} 6_5	61.02 61.09	19.5 570	18.1 211
252	1362.70		70	-	-	b b	5_{-2} 5_2	6_0 6_4	62.70 62.96	215 250	50 76
253	1363.17		80	-	-	b	5_3	6_3	63.16	745	226
254	1365.9		2	-	-						
255	1368.60		57	-	-	b	5_0	6_2	68.74	347	89
256	1369.78		6	80	-	b b	12_{11} 12_{-12}	12_{-9} 12_{-10}	69.89 70.02	3.8 1.3	3.5 1.2
257	1370.95		4	74	-	c	3_3	4_3	70.9	3.2	4.6
258	1372.28		17	-	-	b	9_{-5}	10_{-5}	72.17	52.5	31.7
259	1373.76		76	-	-	b	5_1	6_1	73.76	1070	275
260	1375.09		70	-	-	b	4_{-3}	5_{-1}	75.13	670	107

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_{τ}	J''_{τ}	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
261	1376.3	Complete Absorption (261–280)	3	-	-						
262	1378.04		35	-	-	b b	10_{-9} 10_{-8}	11_{-11} 11_{-8}	77.98 78.07	263 19.5	139 13.3
263	1378.5		6	-	-	b	7_{-5}	7_{1}	78.66	17.2	5.5
264	1379.63		25	-	-	b b	8_{-4} 10_{-7}	9_{-4} 11_{-9}	79.5 79.66	45.5 58.5	20.9 39.8
265	1382.11		7	85	-	b	10_{-5}	11_{-7}	82.10	18.0	14.9
266	1383.40		5	44	-						
267	1384.26		4	35	-	c	7_{-5}	8_{-5}	83.8	0.56	1.26
268	1386.51		56	-	-	b	7_{-3}	8_{-3}	86.24	311	110
269	1387.55		82	-	-	b	4_{3}	5_{5}	87.50	2160	548
270	1390.0		4	-	-	b	5_{-3}	5_{3}	90.46	22.7	4.9
271	1390.95		12	-	-	b b	11_{-10} 11_{-11}	11_{-8} 11_{-9}	90.78 91.07	4.5 13.4	3.1 9.3
272	1392.38		5	-	-						
273	1394.50		88	-	-	b b b	9_{-7} 4_{1} 6_{-2}	10_{-7} 5_{3} 7_{-2}	94.46 94.55 94.58	159 2305 233	77 500 65
274	1395.81		75	-	-	b	4_{2}	5_{2}	96.00	770	167
275	1397.74		55	-	-	b b	9_{-6} 9_{-9}	10_{-8} 10_{-9}	97.51 97.78	54 685	30 280
276	1399.16		82	-	-	b c	4_{-1} 7_{-7}	5_{1} 8_{-7}	99.15 00.8	2170 1.9	414 3.6
277	1402.0		0	5	-	c	7_{-6}	8_{-8}	01.9	0.63	1.2
278	1403.54		8	-	-	b	9_{-4}	10_{-6}	03.38	17	10
279	1404.98		80	-	-	b	5_{-1}	6_{-1}	05.10	1432	326
280	1407.09		1	22	-						

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
281	1408.51	↑	3	46	-	c	2_1	3_3	08.3	5.3	5.8
282	1409.94		24	85	-	b	8_{-6}	9_{-6}	09.91	135	43
283	1411.52		27	-	-	b b	10_{-3} 10_{-9}	11_{-5} 10_{-7}	11.33 11.43	5.2 42	5.1 23
284	1411.91		26	-	-	b b	5_{-5} 10_{-10}	5_1 10_{-8}	11.91 11.98	73.5 14	14.0 7.7
285	1414.99		5	38	-	Possibly H_2O^{18} b 3_3 4_3					
286	1416.11		41	-	-	b	8_{-5}	9_{-7}	16.09	382	149
287	1417.39		69	-	-	b b	8_{-8} 8_{-7}	9_{-8} 9_{-9}	17.39 17.64	402 1225	181 392
288[h]	1419.3		95	-	-	b b	4_0 3_3	5_0 4_3	19.04 19.55	935 5805	177 1090
289	1423.90	Complete Absorption	73	-	-	b b	3_{-2} 7_{-5}	4_0 8_{-5}	23.90 24.25	625 890	94 269
290	1425.83		0	19	-	c	6_{-3}	7_{-5}	26.3	0.5	0.9
291	1426.60		0	45	-	c	3_{-1}	4_{-1}	26.6	4.1	4.5
292	1428.31		21	-	-	b	8_{-3}	9_{-5}	28.24	128	58
293	1429.97		80	-	-	b	3_0	4_2	30.01	1580	258
294	1432.06		22	-	-	b	9_{-8}	9_{-6}	31.99	41	16
295	1433.31		40	-	-	b b	9_{-9} 4_{-4}	9_{-7} 4_2	33.21 33.49	123 36	38 5.7
296	1435.77		57	-	-	b	7_{-4}	8_{-6}	35.51	292	88
297	1436.72		93	-	-	b b b b	7_{-7} 3_1 6_{-4} 7_{-6}	8_{-7} 4_1 7_{-4} 8_{-8}	36.54 36.67 36.89 37.18	2540 5150 585 835	650 840 143 214
298	1440.64		2	28	-						
299	1441.42		2	45	-	b	11_{-8}	11_{-6}	41.42	3.8	3.2
300	1442.80	↓	0	9	-						

TABLE 1— Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification $J'_{\tau} - J''_{\tau}$	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
301	1445.09	Complete Absorption (301–320)	7	60	-	b 11_{-9} 11_{-7} b 9_{-2} 10_{-4}	45.05 45.12	11.8 4.9	9.8 3.4
302	1446.49		13	65	-	b 3_{-3} 3_{3}	46.52	60	8.2
303	1447.91		85	-	-	b 5_{-3} 6_{-3}	47.88	2955	594
304	1450.53		1	19	-	Possibly H_2O^{18} b 6_{-5} 7_{-7}			
305	1452.01		58	-	-	b 8_{-7} 8_{-5}	52.20	324	98
306	1453.4		1	-	-				
307	1454.59		44	-	-	b 8_{-8} 8_{-6}	54.64	109	33
308	1455.26		75	-	-	b 6_{-6} 7_{-6}	55.30	1600	310
309	1456.49		95	-	-	b 6_{-5} 7_{-7}	56.45	4785	995
310	1457.09		89	-	-	b 2_{1} 3_{3} b 6_{-3} 7_{-5}	57.11 57.11	8400 1650	1210 402
311	1458.24		89	-	-	b 2_{2} 3_{2}	58.39	2880	413
312	1459.26		84	-	-	b 4_{-2} 5_{-2}	59.30	1525	260
313	1460.76		2	68	-				
314	1462.71		2	-					
315	1464.92		92	-	-	b 2_{-1} 3_{1}	64.91	4800	635
316	1466.59		4	-	-	Possibly H_2O^{18} b 3_{-1} 4_{-1}			
317	1467.61		6	-	-	Possibly H_2O^{18} b 5_{-5} 6_{-5}			
318	1469.3		2	-	-				
319	1472.0		98	-	-	b 7_{-6} 7_{-4} b 3_{-1} 4_{-1}	71.77 71.92	441 6580	107 960
320	1473.44		94	-	-	b 5_{-5} 6_{-5}	73.46	7980	1410

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification $J'_\tau - J''_\tau$	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
321	1476.29	↑	94	-	-	b 5_{-4} 6_{-6} b 7_{-7} 7_{-5}	76.09 76.48	2500 800	440 190
322	1478.1		2	-	-				
323	1480.4		1	40	-				
324	1481.33		62	-	-	b 5_{-2} 6_{-4} b 8_{-1} 9_{-3}	81.37 81.73	890 36	180 18
325	1482.5		0	40	-				
326	1484.3		0	18	-	b 10_{-1} 11_{-3}	84.44	1.5	1.7
327	1486.27		40	-	-	b 9_{-7} 9_{-5}	86.22	140	63
328	1487.34		91	-	-	b 2_0 3_0	(87.34)	2970	390
329	1489.23		85	-	-	b 8_{-5} 8_{-3} b 6_{-1} 7_{-3}	89.11 89.19	343 456	120 122
330	1489.81	Complete Absorption	88	-	-	b 6_{-5} 6_{-3}	89.81	1685	340
331	1490.81		88	-	-	b 4_{-4} 5_{-4}	90.76	3890	590
332	1496.23		94	-	-	b 4_{-3} 5_{-5}	96.27	11560	1760
333	1498.79		92	-	-	b 1_0 2_2 b 6_{-6} 6_{-4}	(98.79) 98.86	3145 610	390 120
334	1500.51		10	-	-	Possibly also H_2O^{18} b 3_{-3} 4_{-3} b 9_{-4} 9_{-2}	00.54	29	15
335	1501.83		52	-	-	b 7_{-4} 7_{-2}	01.83	280	77
336[j]	1506		99	-	-	b 1_1 2_1 b 5_{-4} 5_{-2} b 3_{-3} 4_{-3}	05.57 06.68 07.09	11460 1065 14670	1370 180 1960
337	1508.55		97	-	-	b 4_{-1} 5_{-3}	08.49	3340	560
338	1509.79		85	-	-	b 8_{-1} 8_1 b 6_1 6_3 b 5_3 5_5	09.56 09.72 09.73	111 365 540	54 111 137
339	1510.56	↓	43	-	-	b 7_5 7_7 b 6_2 6_4	10.58 10.56	20 122	12 37

TABLE 1— Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification $J'_{\tau} - J''_{\tau}$	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
340	1512.37	↑	90	-	-	b 7_{1} 7_{3}	12.22	159	60
						b 7_{-2} 7_{0}	12.30	185	59
						b 6_{-3} 6_{-1}	12.34	1735	396
341	1515.01		72	-	-	b 6_{-1} 6_{1}	14.84	980	250
342	1516.77		94	-	-	b 5_{0} 5_{2}	16.32	475	103
						b 4_{1} 4_{3}	16.73	1420	267
343	1517.50		96	-	-	b 3_{-2} 4_{-4}	17.59	4680	620
						b 4_{2} 4_{4}	17.95	470	88
344	1520.36	Complete Absorption	93	-	-	b 5_{1} 5_{3}	20.18	1470	320
						b 5_{-2} 5_{0}	20.24	1330	253
345	1521.4		95	-	-	b 4_{-3} 4_{-1}	21.25	5230	760
						b 5_{-5} 5_{-3}	21.25	3870	650
346	1522.67		92	-	-	b 2_{-2} 3_{-2}	22.66	5300	650
347	1525.1		72	-	-	b 6_{0} 6_{2}	24.86	347	88
348	1525.52		92	-	-	b 4_{-1} 4_{1}	25.45	4100	670
349	1527.38		79	-	-	b 7_{-5} 7_{-3}	27.48	1254	335
350	1528.66		75	-	-	b 3_{0} 3_{2}	28.62	1240	179
351	1531.71	↓	55	-	-	b 7_{-1} 7_{1}	31.64	595	185

Note: Between lines 351 and 352 the absorption has not been measured, since our resolution is not improved over that published [3]. The calculated spectrum from our energy levels yields results agreeing to ± 0.2 cm^{-1} with the earlier work.

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification J'_τ — J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
352	1761.88	Complete Absorption	88	-	-	b 6_{-3} 5_{-3}	61.86	6388	1070
353	1764.22		7	-	-	Possibly H_2O^{18} b 3_3 2_1			
354	1765.40		6	-	-	b 10_{-6} 10_{-8}	65.38	29	16
355	1767.3		20	-	-	b 9_{-2} 9_{-4}	67.06	54	25
356	1768.20		87	-	-	b 9_{-7} 9_{-9} b 9_{-9} 8_{-7} b 9_{-8} 8_{-8}	68.06 68.23 68.41	275 2910 970	88 740 250
357	1771.38		91	-	-	b 3_2 2_2	71.45	6050	725
358	1772.64		93	-	-	b 3_3 2_1	72.80	17850	2140
359	1775.64		77	-	-	b 7_{-4} 6_{-4}	75.61	1320	260
360	1778.6		22	-	-	b 10_{-3} 10_{-5} c 4_1 3_1	78.57 78.64	55 8	33 8
361	1779.14		49	-	-	b 8_{-4} 7_{-2} b 10_{-5} 10_{-7}	79.2 79.15	210 84	59 46
362	1780.70		84	-	-	b 4_0 3_{-2} b 8_{-6} 7_{-4}	80.77 80.92	1485 715	181 174
363	1781.96		28	-	-	b 9_{-3} 8_{-1}	82.04	80	33
364	1783.95		23	-	-	b 4_2 4_{-4}	84.08	80	11
365	1784.93		76	-	-	b 10_{-9} 9_{-9}	85.03	1810	580
366	1788.45		18	-	-	b 8_2 8_0 b 10_{-8} 10_{-10}	88.38 88.79	73 34	30 14
367	1790.1		37	-	-	b 10_{-7} 10_{-9} b 11_{-7} 11_{-9}	90.09 90.0	104 27	42 18
368	1791.02		88	-	-	b 8_{-5} 7_{-5}	91.05	2210	540
369	1792.63		92	-	-	b 4_1 3_1	92.73	12050	1590
370	1795.22		41	-	-	b 6_4 6_2	95.28	235	60

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Laboratory: 110° C <8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification J'_{τ} — J''_{τ}			CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
371	1796.03	Complete Absorption	79	-	-	b b b	5_{5} 6_{3} 7_{2}	5_{3} 6_{1} 7_{0}	95.90 96.19 96.39	790 710 165	170 180 53
372	1796.87		30	-	-	b	8_{1}	8_{-1}	96.98	217	89
373	1799.63		86	-	-	b	4_{2}	3_{0}	99.84	3860	506
374	1801.36		55	-	-	b	11_{-11}	10_{-9}	01.50	760	310
375	1802.43		65	-	-	b	9_{-7}	8_{-5}	02.62	1065	320
376	1805.17		24	-	-	b	5_{1}	5_{-5}	05.16	181	27
377	1807.75		52	-	-	b	9_{-6}	8_{-6}	07.76	362	110
378	1808.62		3	-	-	b b	11_{-9} 11_{-8}	11_{-11} 11_{-10}	08.6 09.41	36 12	18 6
379	1810.63		81	-	-	b	5_{0}	4_{0}	10.71	2400	360
380	1812.22		54	-	-	b	9_{-5}	8_{-3}	12.26	342	106
381	1814.73		4	-	-						
382	1815.6		3	-	-						
383	1817.47		40	-	-	b	12_{-11}	11_{-11}	17.52	290	154
384	1821.46		7	-	-	b	10_{-4}	9_{-2}	21.50	13.1	6
385	1822.82		37	-	-	b	10_{-8}	9_{-6}	22.87	157	61
386	1825.31		87	-	-	b b	6_{-1} 10_{-7}	5_{-1} 9_{-7}	25.10 25.52	3940 478	690 186
387	1829.42		88	-	-	b	5_{-1}	4_{-3}	29.24	1850	250
388	1830.26		91	-	-	b	5_{1}	4_{-1}	30.14	6150	900
389	1833.39		22	-	-	b	13_{-13}	12_{-11}	33.39	100	72
390	1834.76		6	-	-	b	11_{1}	11_{-1}	34.52	4.2	5.1

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Intensity: Laboratory: 110° C (8 Atmo-M	Intensity: Laboratory: 110° C 8 Atmo-M	Identification $J'_{\tau} - J''_{\tau}$			CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
391	1836.07	Complete Absorption (arrow spanning lines 391–410)	5	-	-	b Possibly H_2O^{18} b	6_{0} 4_{3}	6_{-6} 3_{3}	35.85	27	4.9
392	1837.32		65	-	-	b b	7_{-2} 3_{2}	6_{-2} 2_{-2}	37.39 37.54	680 47	147 5
393	1839.29		4	20	-	c	4_{3}	3_{3}	39.1	11	12
394	1840.5		0	7	-	b	10_{2}	10_{0}	40.5	4.5	3.9
395	1842.25		37	-	-	b b	11_{-9} 10_{-6}	10_{-7} 9_{-4}	42.10 42.23	187 52	103 25
396	1844.24		92	-	-	b b	11_{-8} 4_{3}	10_{-8} 3_{3}	43.44 44.20	62 16000	34 2300
397	1845.4		52	-	-	b b b	6_{5} 7_{5} 8_{3}	6_{3} 7_{3} 8_{1}	45.57 45.54 46.09	260 210 87	79 80 42
398	1847.82		67	-	-	b	8_{-3}	7_{-3}	47.87	945	253
399	1848.80		15	-	-	b	14_{-13}	13_{-13}	48.80	31	30
400	1852.44		8	19	-	b	5_{3}	5_{-3}	52.38	64	9.5
401	1854.1		2	4	-	b	4_{4}	4_{-2}	54.12	9.7	1.3
402	1856.30		4	11	-	b	6_{2}	6_{-4}	56.40	28.4	5.7
403	1858.52		32	70	-	b	9_{-4}	8_{-4}	58.48	145	50
404	1859.73		8	40	-	b	11_{-5}	10_{-3}	59.69	16.6	12
405	1860.96		10	39	-	b	12_{-10}	11_{-8}	60.96	22.1	15
406	1861.51		18	52	-	b	12_{-9}	11_{-9}	61.51	66.6	55
407	1863.1		0	4	-	c	5_{3}	4_{1}	63.6	4.5	5.7
408	1864.07		7	34	-	b	15_{-15}	14_{-13}	64.06	8.8	12
409	1866.39		66	-	-	b	6_{0}	5_{-2}	66.44	825	140
410	1867.94		82	-	-	b b	5_{2} 4_{1}	4_{2} 3_{-3}	67.81 68.12	2400 388	390 47

TABLE 1— Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Intensity: Laboratory: 110° C (8 Atmo-M	Intensity: Laboratory: 110° C 8 Atmo-M	Identification $J'_\tau - J''_\tau$			CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
411	1869.25	↑	90	-	-	b	5_3	4_1	69.34	7220	1180
412	1870.78		45	-	-	b	10_{-5}	9_{-5}	70.91	179	80
413	1876.67		5	11	-	b	7_{-1}	7_{-7}	76.59	25.0	5.2
414	1879.43		12	50	-	b	13_{-11}	12_{-9}	79.40	28.2	26
415	1882.3		0	2	-						
416	1884.63	Complete Absorption	36	62	-	b	6_{-2}	5_{-4}	84.64	243	37
417	1885.28		9	42	-	b	11_{-6}	10_{-6}	85.36	22	13
418	1889.59		87	95	-	b	6_1	5_1	89.60	3715	709
419	1892.63		2	17	-	b	12_{-8}	11_{-6}	(92.63)	7.1	5.8
420	1893.87		7	25	-	b	7_7	7_5	93.63	52	23
421	1895.27	↓	65	85	-	b b b	8_5 6_2 9_5	8_3 5_0 9_3	94.99 95.27 95.19	37 1230 18	21 230 14
422	1897.57	40	5	32	-	b	14_{-11}	3_{-11}	(97.57)	8.1	10.4
423	1898.81	10	0	6	-						
424	1901.87	75	10	40	-	b	12_{-7}	11_{-7}	01.86	22	18
425	1904.50	99	23	43	-	b	5_0	4_{-4}	04.40	159	21
426	1908.12		53	82	-	b	7_0	6_0	08.12	555	128
427	1910.09		68	87	-	b	7_{-1}	6_{-3}	09.95	925	186
428	1914.70	99	3	25	-	Possibly H_2O^{18} b 7_1 6_{-1}					
429	1915.30		1	15	-	d	6_{-5}	7_{-7}	15.16	0.07	0.10
430	1918.08		82	-	-	b	5_5	4_3	18.08	7660	1440

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				$J'_\tau - J''_\tau$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
431	1919.3	}	4	-	-						
432	1920.7	} 99	3	-	-	b	9_{-1}	9_{-7}	20.29	9.2	4.6
433	1922.42	}	54	-	-	b	8_{-1}	7_{-1}	22.39	665	193
434	1923.14	}	63	-	-	b	7_{1}	6_{-1}	23.14	1490	340
435	1927.82	30	3	-	-						
436	1933.09	97	14	-	-	b	9_{-2}	8_{-2}	33.23	86	32
437	1935.24	15	0	20	-						
438	1937.87	40	0	40	-	b	8_{2}	8_{-4}	37.17	2.8	1.1
439	1939.2	15	0	9	-	b	9_{1}	9_{-5}	39.51	4.7	2.1
440	1940.2	}	3	-	-	b	8_{7}	8_{5}	40.35	8.0	5.8
441	1941.73	}	23	-	-	b b b	10_{-3} 9_{7} 7_{3}	9_{-3} 9_{5} 7_{-3}	41.78 41.82 41.89	86 5.0 9.5	43 5 2.6
442	1942.49	} 99	80	-	-	b b	6_{3} 6_{4}	5_{3} 5_{2}	42.61 42.86	3026 1009	660 220
443	1945.28	}	42	-	-	b	7_{-3}	6_{-5}	45.14	287	51
444	1946.25	}	39	-	-	b	6_{-1}	5_{-5}	46.24	364	55
445	1949.15	70	9	71	-	b	11_{-4}	10_{-4}	49.28	9.2	6.2
446	1949.96	10	0	10	-	b	6_{4}	6_{-2}	50.31	2.5	0.5
447	1950.97	50	0	10	-	b	6_{1}	6_{-5}	51.15	9.5	1.7
448	1954.99	99	36	97	-	b	8_{0}	7_{-2}	55.02	202	56
449	1956.25	97	2	75	-	b	4_{3}	3_{-1}	56.24	28.3	3.5
450	1957.62	75	8	83	-	d b	4_{-3} 12_{-5}	5_{-5} 11_{-5}	56.90 57.66	0.15 8.1	0.17 7.8

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory: Air only	Laboratory: 110° C (8 Atmo-M	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
451	1961.19	96	26	95	-	b	8_{-2}	7_{-4}	61.25	108	25
452	1966.36	99	52	99	-	b	7_2	6_2	66.45	469	120
453	1967.49	99	66	99	-	b	7_3	6_1	67.54	1390	357
454	1970.0	10	0	52	-	b	11_{-1}	11_{-7}	69.35	0.8	0.6
455	1975.43	5	2	32	-	e e	5_0 8_{-8}	6_{-1} 9_{-9}	72.75 75.84	0.2 0.1	0.3 0.3
456	1976.19	83	3	50	-	b	5_2	4_{-2}	76.19	29	4
457	1977.6	14	0	8	-	Possibly H_2O^{18} b	6_5	5_5			
458	1981.32	40	2	50	-	e	6_{-4}	7_{-5}	80.83	0.25	0.45
459	1982.1	15	1	27	-						
460	1984.61	33	0	25	-	b b	9_9 9_{-3}	9_7 9_{-9}	84.40 84.62	1.0 2.2	1.3 0.7
461	1988.53	99	56	99	-	b b	4_4 8_1	3_{-2} 7_1	87.33 88.53	4.3 570	0.5 184
462	1992.06	99	71	99	-	b	6_5	5_5	92.14	2640	670
463	1992.6	99	66	99	-	b b b	8_2 9_{-1} 7_{-2}	7_0 8_{-3} 6_{-6}	92.50 93.31 93.35	211 183 65	68 65 11
-	-	-	0	-	-	e	7_{-6}	8_{-7}	95.08	0.26	0.5
464	1998.94	94	17	85	-	b	6_1	5_{-3}	98.94	144	24
465	2000.90	10	0	20	-						
466	2003.20	8	0	10	-	d d	2_{-1} 1_{-1}	3_{-3} 2_{-1}	02.96 03.29	0.18 0.20	0.16 0.17
-	-	0	-	0	-	e	5_{-2}	6_{-3}	04.14	0.31	0.4
467	2005.8	27	0	12	-	c	6_5	5_5	04.8	1.3	2.7
468	2007.66	95	26	92	-	b	9_0	8_0	07.77	67.5	28
469	2009.30	93	9	85	-	b	8_{-4}	7_{-6}	09.47	37.8	7.9
470	2012.3	3	0	8	-	Possibly H_2O^{18} b e	7_5 4_0	6_3 5_{-1}	 12.29	 0.53	 0.7

TABLE 1 — Continued.

Line Number	OBSERVED DATA					Identification			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity				$J'_\tau - J''_\tau$			Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C (8 Atmo-M)	110° C 8 Atmo-M						
471	2016.78 }	99 (471–473)	73	-	-	b	7_5	6_3	16.76	1235	377
472	2018.30 }		50	-	-	b	9_1	8_{-1}	18.77	202	83
473	2018.92 }		34	-	-	b	9_{-3}	8_{-5}	19.18	93	28
474	2022.95	86	30	95	-	b	10_{-1}	9_{-1}	23.09	62.5	34
475	2026.58	90	10	84	-	{b b	7_0 5_3	6_{-4} 4_{-3}	26.79 27.00	41.3 23.6	8.3 3.1
476	2030.03	16	0	10	-						
477	2034.03	52	0	4	68	{b b e	11_{-2} 8_1 5_{-4}	10_{-2} 8_{-5} 6_{-5}	34.35 34.12 34.13	5.8 0.87 0.63	4.4 0.26 0.82
478	2037.54	75	5	8	80	b	10_{-2}	9_{-4}	37.54	15.3	7.0
479	2041.35	93	31	70	95	{b b b	12_{-3} 8_3 8_4	11_{-3} 7_3 7_2	41.35 41.39 41.60	4.2 384 128	4.6 146 48
480	2043.97	93	9	18	86	b	8_{-3}	7_{-7}	44.00	102	21
481	2046.58	70	4	13	80	b	10_0	9_{-2}	46.64	20.8	11
482	2048.7	?	0	0	7	e	3_0	4_{-1}	48.66	0.71	0.76
483	2050.8	?	0	0	11	b	8_4	8_{-2}	51.08	0.37	0.12
484	2051.49	?	0	0	18	e	3_{-1}	4_{-2}	51.33	0.31	0.32
485	2053.06	?	0	0	12						
486	2053.96	?	0	0	16	{e e	4_{-4} 4_{-3}	5_{-5} 5_{-4}	53.84 54.47	0.96 0.31	1.06 0.34
487	2060.55	?	8	16	80	b	8_{-1}	7_{-5}	60.55	92	22.2
488	2064.90	?	29	50	-	{b b	7_7 9_2	6_5 8_2	64.87 65.02	690 46.7	255 22.4
489	2065.83	?	13	30	-	b	9_3	8_1	65.91	141	67.5
490	2068.74	?	0	3	8*	{e CO	2_2 P(18)	3_1	67.98 68.85	0.60	0.58

TABLE 1—Continued.

Line Number	OBSERVED DATA					Identification $J'_\tau - J''_\tau$	CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity					Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory					14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M				
491	2072.9	?	0	6	12*	b 6_6 — 6_0 b 6_2 — 5_{-4} CO P(17)	72.70 72.68 73.27	0.17 6.1	0.04 0.92
492	2074.22	?	0	10	58	e 3_{-2} — 4_{-3} b 9_{-5} — 8_{-7}	73.80 74.26	1.24 45.1	1.21 11.5
493&	2077.3	?	0	8	14*	e 2_0 — 3_{-1} CO P(16)	76.83 77.65	1.12	1.02
494	2078.61	?	0	11	60	b 11_{-1} — 10_{-3}	78.67	15.6	11.1
495	2081.98	?	0	10	34*	CO P(15) b 10_{-4} — 9_{-6}	82.00 82.02	 8.95	 3.40
496	2086.52	?	0	8	17*	CO P(14) b 11_{-3} — 10_{-5}	86.32 86.52	 10.6	 6.4
497	2087.54	?	5	13	61	b 10_1 — 9_1	87.54	45.4	28.7
498	2090.20	?	16	38	86	b 8_5 — 7_5 b 10_2 — 9_0	90.19 90.2	286 15.1	130 9.5
499	2093.36	?	-	-	17	e 2_{-2} — 3_{-3} e 2_{-1} — 3_{-2}	93.02 93.73	1.64 0.53	1.40 0.46
500	2095.29	?	-	-	23*	b 8_3 — 8_{-3} e 4_4 — 4_3	95.14 95.28	0.90 0.72	0.31 1.01
501	2097.43	48	-	-	48	b 9_{-4} — 8_{-8}	97.48	14.1	3.53
502	2100.46	50	-	-	61	b 9_{-2} — 8_{-6}	00.46	13.9	4.20
503	2103.31	?	-	-	17*	e 1_1 — 2_0 CO P(10)	03.13 03.27	0.31	0.25
-	2105.93†	20	-	-	-	b 5_5 — 4_{-1}	05.86	5.35	0.77
504	2106.45†	40	-	-	29	b 6_3 — 5_{-1}	06.45	14.4	2.52
505	2107.47	?	-	10	55	b 11_0 — 10_0	07.9	4.25	3.61
506	2111.59	?	-	-	13*	d 2_1 — 2_{-1} CO P(8)	11.51 11.54	0.12	0.10
507	2114.86	80?	-	44	99	d 3_{-3} — 2_{-1} e 1_0 — 2_{-1} b 11_1 — 10_{-1} b 9_5 — 8_3 d 2_{-1} — 1_{-1}	14.28 14.45 14.50 15.18 16.47	0.24 1.01 12.6 107.5 0.29	0.20 0.82 10.7 62.5 0.22

Line Number	OBSERVED DATA					Identification $J'_{\tau} - J''_{\tau}$			CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity							Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory							14° C	110° C
			Air only	110° C <8 Atmo-M	110° C 8 Atmo-M						
508	2119.48	?	-	-	7*	e CO	4_{1} P(6)	4_{2}	19.07 19.68	0.18	0.22
509	2121.54	20	-	-	28	b e	7_{2} 4_{2}	6_{-2} 4_{1}	21.48 21.73	6.5 0.53	1.37 0.48
510	2122.58	2	-	-	25	e e e	3_{2} 3_{3} 3_{-2}	3_{3} 3_{2} 3_{-1}	22.31 22.67 23.13	1.14 0.38 0.25	1.23 0.41 0.22
511	2124.27	30?	-	-	62	b	12_{-1}	11_{-1}	24.39	3.15	3.81
-	2125.00†	10	-	-	-	b	7_{1}	6_{-5}	24.87	13.7	2.36
512	2127.57	?	-	-	5*	CO	P(4)		27.68		
513	2129.54	39	-	-	5						
514	2131.58	?	-	-	10*	d CO	3_{-2} P(3)	2_{-2}	31.58 31.63	0.10	0.08
515	2136.06	63?	9	31	96	b	8_{7}	7_{7}	36.20	135.5	76.8
516	2137.12	55	0	-	75	b b	6_{4} 8_{1}	5_{-2} 7_{-3}	36.86 37.35	3.5 18.3	0.60 4.83
-	2138.29†	15	2	0	?	b	10_{-6}	9_{-8}	38.38	5.6	1.88
517	2139.30	?	4	30	95	b	10_{3}	9_{3}	39.37	25.7	19.8
518	2141.3	?	0	-	2						
519	2142.4	8	0	-	2	e	2_{1}	2_{2}	41.94	0.52	0.47
520	2145.41	52	0	12	77	e b	2_{2} 10_{-3}	2_{1} 9_{-7}	44.63 45.64	1.57 20.3	1.40 7.8
521	2147.38	?	0	9	55	d b	4_{-3} 11_{-5}	3_{-3} 10_{-7}	45.68 47.42	0.27 7.8	0.24 3.9
522	2151.24	?	0	-	20	d e	2_{1} 1_{0}	1_{1} 1_{1}	48.10 51.04	0.08 0.39	0.06 0.31
523	2152.58	45	0	-	50	b	10_{-5}	9_{-9}	52.75	16.3	5.15
524	2154.68	?	0	-	12*	d CO	5_{-5} R(2)	4_{-3}	54.60 54.60	0.25	0.25

TABLE 1—Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Laboratory: Air only	Laboratory: 110° C (8 Atmo-M)	Laboratory: 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
525	2156.60	22	0	-	15	b	9_0	8_{-4}	56.56	5.3	1.8
526	2158.26	?	0	-	6*	{e CO	4_0 R(3)	4_{-1}	58.22 58.30	0.33	0.36
527	2161.75	?	0	-	84	b	9_7	8_5	61.88	51	36
528	{2162.90† 2163.46†	10 15 }	0	-	69	{b b	11_2 11_3	10_2 10_1	62.90 63.46	2.48 7.44	2.58 7.73
529	2165.50	?	0	-	8*	{CO b	R(5) 12_{-3}	 12_{-9}	65.60 65.68	 0.05	 0.05
530	2167.35	?	0	-	20	b	13_{-1}	12_{-3}	(67.35)	0.60	1.06
531	2169.17	?	0	-	6*	CO	R(6)		69.20		
532	2171.31	15?	0	-	15	b	7_3	6_{-3}	71.38	10.7	2.12
533	2172.43	?	0	-	16*	{e d CO	2_0 6_{-6} R(7)	2_{-1} 5_{-4}	72.06 72.35 72.76	0.60 0.07	0.49 0.08
534	2175.09	10?	0	-	11	d	6_{-5}	5_{-5}	75.14	0.20	0.22
535	2176.45	?	0	-	7*	CO	R(8)		76.28		
536	2178.99	?	0	-	8	d	4_{-1}	3_{-1}	78.91	0.17	0.16
537	2179.87	?	0	-	10*	CO	R(9)		79.77		
538	2181.41	?	0	-	40	b	10_{-1}	9_{-5}	81.61	8.84	3.98
539	2183.33	?	0	-	6*	CO	R(10)		83.22		
540	2185.41	?	0	-	38	{b b	8_0 12_1	7_{-6} 11_1	85.24 85.37	2.0 1.9	0.42 2.75
541	2187.05	?	0	-	28*	{b b	12_2 10_5	11_0 9_5	87.0 87.04	0.65 16.6	0.92 15.8
542	2189.69	?	0	-	11	d	7_{-7}	6_{-5}	89.52	0.13	0.16
543	2190.4	?	0	-	8*	{CO d	R(12) 7_{-6}	 6_{-6}	90.02 90.7	 0.04	 0.05
544	2191.83	?	0	-	2	d	3_2	2_2	91.34	0.086	0.07

TABLE 1—Continued.

Line Number	OBSERVED DATA					Identification $J'_\tau - J''_\tau$	CALCULATED DATA		
	Wave Number cm⁻¹ (vac)	Intensity					Wave Number cm⁻¹ (vac)	Intensity	
		Solar	Laboratory					14° C	110° C
			Air only	110° C (8 Atmo-M	110° C 8 Atmo-M				
545	2193.36	?	0	-	9*	d 3_3 2_1 CO R(13)	92.66 93.36	0.25	0.22
546	2194.50	?	0	-	13	b 11_{-4} 10_{-8}	94.37	2.25	1.11
547	2196.69	?	0	-	5*	CO R(14)	96.66		
548	2198.63	?	0	-	11	e 2_{-1} 1_0	98.42	0.40	0.31
549	2200.29	?	0	-	25*	b 11_{-7} 10_{-9}	00.4	5.5	2.23
550	2201.2	?	0	-	4				
551	2202.0	?	0	-	2				
552	2203.23	?	0	-	4*	CO R(16)	03.16		
553	2205.19	?	0	-	60	b 9_9 8_7	05.30	19.3	18.1
554	2206.48	?	0	-	25	e 2_{-2} 1_{-1}	06.53	1.74	1.31
555	2208.83	?	0	-	16	e 2_0 1_1 b 11_{-6} 10_{-10}	08.65 08.96	1.12 1.88	0.86 0.75
556	2209.9	?	0	-	5	b 13_1 12_{-1}	(09.9)	0.42	0.87
557	2210.4	?	0	-	5	b 8_2 7_{-4}	10.76	2.38	0.58
558	2211.50	?	0	-	40	b 11_5 10_3 b 11_{-2} 10_{-6}	11.50 12.65	4.83 1.30	6.27 0.79
559	2214.0	?	0	-	8	e 3_0 2_1	14.09	0.80	0.70
560	2214.3	?	0	-	8				
561	2215.80	?	0	-	5				
562	2218.48	?	0	-	26	e 3_{-2} 2_{-1}	18.36	2.00	1.73
563	2221.87	?	0	-	4	d 9_{-9} 8_{-7}	21.96	0.10	0.18
564	2223.61	?	0	-	4				

TABLE 1 — Continued.

Line Number	OBSERVED DATA: Wave Number cm⁻¹ (vac)	Intensity: Solar	Intensity: Laboratory, Air only	Intensity: Laboratory, 110° C <8 Atmo-M	Intensity: Laboratory, 110° C 8 Atmo-M	Identification	J'_τ	J''_τ	CALCULATED DATA: Wave Number cm⁻¹ (vac)	Intensity: 14° C	Intensity: 110° C
565	2225.84	?	0	-	8	b	6_5	5_1	25.45	1.55	0.29
						e	3_{-3}	2_{-2}	25.87	0.72	0.57
566	2227.30	?	0	-	16	d	4_4	3_2	27.09	0.07	0.08
						d	4_3	3_3	27.45	0.22	0.24
						b	6_3	5_{-5}	27.59	0.06	0.07
567	2231.01	?	0	-	40	b	10_7	9_7	31.01	7.10	9.0
568	2232.93	?	0	-	10	e	3_{-1}	2_0	33.13	0.55	0.45
569	2235.62	?	0	-	25	b	12_3	11_3	35.62	1.30	2.30
570	2237.76	?	0	-	10	e	4_{-3}	3_{-2}	37.64	0.66	0.58
571	2239.30	?	0	-	8						

†, Frequency obtained from solar spectrum; g, probably due to CO_2; h, this line looks like an unresolved doublet; j, obviously consists of several unresolved components; *, intensity variable, due to CO contaminant.

TABLE 2. Energy Levels of H_2O (cm^{-1}).

J_τ	$V_1V_2V_3$ 000	010	020
0	0.00	1594.59	3151.53
1_{-1}	23.79	1618.41	3175.4
1_0	37.13	1634.94	3196.2
1_1	42.37	1640.48	3202.0
2_{-2}	70.06	1664.93	3222.06
2_{-1}	79.48	1677.07	3237.77
2_0	95.17	1693.62	3255.26
2_1	134.91	1742.51	3316.0
2_2	136.15	1743.64	3317.0
3_{-3}	136.77	1731.92	3289.27
3_{-2}	142.27	1739.63	3300.1
3_{-1}	173.36	1772.30	3334.55
3_0	206.28	1813.87	3387.8
3_1	212.16	1819.16	3392.90
3_2	285.25	1907.60	3500.4
3_3	285.40	1907.71	3500.5
4_{-4}	222.04	1817.35	3375.3
4_{-3}	224.83	1821.63	3381.9
4_{-2}	275.48	1875.42	3438.6
4_{-1}	300.38	1907.94	3482.0
4_0	315.73	1923.04	3495.85
4_1	382.49	2004.89	3597.80
4_2	383.86	2006.12	3598.8
4_3	488.16	2129.60	3746.8
4_4	488.17	2129.60	3746.8
5_{-5}	325.36	1920.70	3479.1
5_{-4}	326.59	1922.80	3482.5
5_{-3}	399.45	2000.80	3565.5
5_{-2}	416.12	2024.24	3598.6
5_{-1}	446.50	2054.07	3627.0
5_0	504.00	2126.44	3719.2
5_1	508.79	2130.52	3722.55
5_2	610.12	2251.67	3868.3
5_3	610.34	2251.83	3868.5
$5_{4,5}$	742.10	2406.24	4052.8

TABLE 2 - Continued.

J_τ	$V_1V_2V_3$		
	000	010	020
6_{-6}	446.71	2041.73	3600.4
6_{-5}	447.24	2042.73	3602.0
6_{-4}	542.87	2146.39	3713.1
6_{-3}	552.92	2161.31	3736.2
6_{-2}	602.67	2211.23	3784.3
6_{-1}	648.97	2271.60	3864.8
6_0	661.54	2282.56	3873.55
6_1	756.76	2398.39	4015.1
6_2	757.70	2399.27	4015.8
6_3	888.67	2552.95	4197.4
6_4	888.71	2552.98	4197.4
$6_{5,6}$	1045.15	2734.24	?4411.0
7_{-7}	586.28	2180.68	3738.6
7_{-6}	586.43	2181.27	3739.5
7_{-5}	704.20	2309.89	3879.05
7_{-4}	709.50	2318.48	3894.5
7_{-3}	782.41	2392.38	3967.4
7_{-2}	816.65	2440.06	4038.7
7_{-1}	842.36	2462.87	4053.0
7_0	927.76	2569.66	?4187.8
7_1	931.23	2572.11	4190.8
7_2	1059.68	2724.15	
7_3	1059.89	2724.30	
$7_{4,5}$	1216.39	2905.43	
$7_{6,7}$	1394.85	3110.02	
8_{-8}	744.09	2337.61	3894.4
8_{-7}	744.14	2337.84	3894.8
8_{-6}	882.97	2490.42	4063.9
8_{-5}	885.64	2495.25	4071.6
8_{-4}	983.09	2595.9	
8_{-3}	1006.14	2630.28	4224.8
8_{-2}	1050.20	2670.75	
8_{-1}	1122.78	2764.75	4383.9
8_0	1131.88	2771.67	
8_1	1255.19	2919.76	
8_2	1255.98	2920.26	
$8_{3,4}$	1411.59	3101.28	
$8_{5,6}$	1590.70	3306.58	
$8_{7,8}$	1789.09	3531.05	
9_{-9}	920.20	2512.37	4068.8
9_{-8}	920.22	2512.50	
9_{-7}	1079.16	2688.26	4266.7
9_{-6}	1080.51	2690.73	
9_{-5}	1202.04	2818.40	
9_{-4}	1216.37	2841.57	
9_{-3}	1283.02	2904.82	
9_{-2}	1341.03	2983.43	
9_{-1}	1360.56	2999.45	
9_0	1475.14	3139.65	
9_1	1477.46	3141.55	
9_2	1631.44	3321.0	
9_3	1631.58	3321.10	
$9_{4,5}$	1810.76	3526.77	
$9_{6,7}$	2009.99	3752.58	
$9_{8,9}$	2225.56	3994.39	
10_{-10}	1114.59	2705.20	4260.7
10_{-9}	1114.59	2705.23	
10_{-8}	1293.22	2903.38	
10_{-7}	1293.80	2904.68	
10_{-6}	1438.19	3058.60	
10_{-5}	1446.23	3072.95	
10_{-4}	1538.31	3162.53	
10_{-3}	1581.53	3224.80	
10_{-2}	1616.49	3253.91	
10_{-1}	1719.36	3383.65	
10_0	1724.80	3387.67	
10_1	1875.24	3565.00	
10_2	1875.72	3565.3	
$10_{3,4}$	2054.55	3770.95	
$10_{5,6}$	2254.55	3997.80	
$10_{7,8}$	2471.59	4241.0	
$10_{9,10}$	2702.09		
$11_{-11,-10}$	1327.25	2916.09	4470.1
11_{-9}	1525.02	3135.9	
11_{-8}	1525.31	3136.66	
11_{-7}	1690.85	3315.0	
11_{-6}	1695.24	3323.55	
11_{-5}	1813.47	3441.22	
11_{-4}	1843.32	3487.59	
11_{-3}	1899.21	3532.75	
11_{-2}	1986.08	3650.84	
11_{-1}	1999.34	?3660.20	
11_0	2143.01	3832.7	
11_1	2144.46	3833.86	
11_2	2322.20	4038.62	
11_3	2322.25	4038.70	
$11_{4,5}$	2522.46	4266.05	
$11_{6,7}$	2740.73		
$11_{8,9}$	2973.07		
$11_{10,11}$	3216.6		

TABLE 2 - Continued.

J_τ	$V_1V_2V_3$		
	000	010	020
$12_{-12,-11}$	1558.07	3144.77	
12_{-10}	1774.75	3386.27	
12_{-9}	1774.88	3386.53	
12_{-8}	1960.38	3587.87	
12_{-7}	1962.60	3592.71	
12_{-6}	2106.7		
12_{-5}	2124.84	3771.13	
12_{-4}	2205.95		
12_{-3}	2275.65	3940.56	
12_{-2}	2300.94		
12_{-1}	2434.14	4123.73	
12_{0}	2437.84		
12_{1}	2613.26	4329.83	
12_{2}	2613.49	4330.0	
$12_{3,4}$	2813.94	4557.87	
$12_{5,6}$	3033.17		
$12_{7,8}$	3267.2		
$12_{9,10}$	3512.8		
$12_{11,12}$	3767.1		
$13_{-13,-12}$	1806.94	3391.46	
13_{-11}	2042.5	3654.28	
13_{-10}	2042.5		
13_{-9}	2247.0	3877.9	
13_{-8}	2248.24		
13_{-7}	2415.95		
13_{-6}	2426.0		
13_{-5}	2534.14		
13_{-4}	2586.5		
13_{-3}	2629.54		
13_{-2}	2748.4		
13_{-1}	2756.61	4443.0	
13_{0}	2927.38		
13_{1}	2928.45	4644.0	
$13_{2,3}$	3128.25		
$13_{4,5}$	3348.2		
$13_{6,7}$	3584.0		
$14_{-14,-13}$	2073.81	3655.74	
$14_{-12,-11}$	2328.2	3940.1	
14_{-10}	2551.0		
14_{-9}	2551.5		
14_{-8}	2740.5		
14_{-7}	2745.5		
14_{-6}	2883.5		
14_{-5}	2919.5		
14_{-4}	2983.6		
14_{-3}	3085.0		
14_{-2}	3101.65		
14_{-1}	3264.2		
14_{0}	3266.36		
14_{1}	3465.18		
14_{2}	3465.4		
$14_{3,4}$	3485.6		
$15_{-15,-14}$	2358.58	3937.87	
$15_{-13,-12}$	2631.6		
15_{-11}	2872.56		
15_{-10}	2872.9		
15_{-9}	3081.2		
15_{-8}	3084.2		
15_{-7}	3252.0		
15_{-6}	3277.0		
15_{-5}	3365.0		
15_{-4}	3446.0		
15_{-3}	3473.0		
15_{-2}	3624.0		
15_{-1}	3628.7		
15_{0}	3824.8		
15_{1}	3826.1		
$15_{2,3}$	4045.8		
$16_{-16,-15}$	2661.2	4237.5	
$16_{-14,-13}$	2953.0		
$16_{-12,-11}$	3211.5		
16_{-10}	3437.7		
16_{-9}	3439.7		
16_{-8}	3640.3		
16_{-7}	3657.1		
$17_{-17,-16}$	2931.5	4554.6	
$17_{-15,-14}$	3291.0		
$17_{-13,-12}$	3567.5		
17_{-11}	3611.7		
17_{-10}	3812.8		
17_{-9}	4047.1		
17_{-8}	4057.3		
$18_{-18,-17}$	3319.4		
$18_{-16,-15}$	3648.0		
$18_{-14,-13}$	3940.8		
$18_{-12,-11}$	4201.8		

TABLE 3. *Series regularities in the* $P_{1,\bar{1}}$, $P_{\bar{1},\bar{1}}$, $P_{\bar{1},1}$, *and* $P_{\bar{3}1}$ *branches of* ν_2

Branch	$(J+\tau)'$	$J'=0$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
$\bar{3},1$	6	------	------	------	------	------	1085. 4	(1066. 2)	1051. 28	(1039. 53)	(1029. 69)	1019. 5	1007. 3					
$\bar{3},1$	4	------	------	------	------	1180. 75	1165. 4	1151. 59	1137. 46	1120. 9	1099. 74	1072. 69	1039. 53					
$\bar{3},1$	2	------	------	------	1284. 37	1265. 42	1244. 18	1218. 63	1187. 00	1149. 48	1106. 76	1060. 14	1010. 86	961. 09				
$\bar{3},1$	0	------	------	(1379. 6)	1349. 39	(1313. 64)	1271. 80	1225. 08	1174. 54	1121. 24	1066. 20	1010. 12	953. 49	896. 65				
$\bar{1},1$	1	------	1498. 79	1464. 92	(1423. 9)	1375. 09	1320. 09	1260. 38	1198. 22	1135. 80	1074. 46	1014. 56	955. 71	897. 77				
$\bar{1},\bar{1}$	0	(1557.5)	1538. 8	1522. 67	1507	1490. 81	1473. 44	1455. 26	(1436. 7)	1417. 39	1397. 74	1378. 04	1358. 06	(1338. 5)	1317. 6	(1296. 7)	1276. 63	1255. 95
$1,\bar{1}$	1	------	1564. 7	1540. 1	1517. 50	1496. 23	1476. 29	1456. 49	(1436. 7)	1417. 39	1397. 74	1378. 04	1358. 06	(1338. 5)	1317. 6	(1296. 7)	1276. 63	1255. 95
$\bar{1},1$	2	------	1505. 8	1487. 34	1472. 0	1459. 26	1447. 91	(1436. 7)	1423. 90	1409. 94	(1394. 5)	(1378. 0)	(1361. 1)	------	1326. 14			
$1,\bar{1}$	3	------	------	(1569. 4)	(1538. 8)	1503. 55	1481. 33	(1457. 0)	1435. 77	1416. 11	(1397. 7)	1379. 63	(1362. 7)	1344. 04				
$\bar{1},1$	3	------	------	1457. 09	1429. 97	1399. 16	1362. 70	1318. 97	1268. 40	1212. 28	1152. 44	1091. 24	1030. 58	(970. 66)				
$\bar{1},\bar{1}$	4	------	------	1458. 24	1436. 72	(1419. 3)	1404. 98	(1394. 5)	1386. 51	1379. 63	1372. 28	(1363. 2)	1352. 41	(1340)	(1326. 14)			
$1,\bar{1}$	5	------	------	------	1591. 9	1558. 5	(1522. 7)	1489. 23	(1457. 1)	1428. 31	1403. 54	1382. 11	(1362. 7)	1345. 51				
$\bar{1},1$	5	------	------	------	1419. 3	1394. 50	1368. 60	1340. 35	1308. 25	1269. 97	(1225. 0)	1173. 76	1117. 71	1058. 69				
$\bar{1},1$	6	------	------	------	1419. 3	1395. 81	1373. 76	1354. 87	(1340. 3)	1329. 90	1323. 31	(1319. 0)	1316. 20					
$\bar{1},1$	7	------	------	------	------	1387. 55	1363. 17	1338. 56	1313. 64	1287. 38	1258. 63	1225. 5	(1187. 0)	1141. 64				
$\bar{1},\bar{1}$	8	------	------	------	------	1387. 55	1363. 17	1339. 55	1317. 04	1296. 67	1280. 09	(1268. 4)	1257. 07					
$\bar{1},1$	9	------	------	------	------	------	1361. 09	1336. 64	1312. 61	1288. 28	1264. 04	1239. 25	1213. 0	1184. 14				
$\bar{1},\bar{1}$	10	------	------	------	------	------	1361. 09	1336. 64	1312. 61	1288. 92	1266. 11	1244. 77	1226. 1					
$\bar{1},1$	11	------	------	------	------	------	------	1339. 23	1314. 82	1290. 59	1266. 63	1242. 90	1219. 1	1195. 41				
$\bar{1},\bar{1}$	12	------	------	------	------	------	------	1339. 23	1314. 82	1290. 59	1266. 63	1242. 90	1220. 43					
$\bar{1},1$ $\bar{1},\bar{1}$	13 14	------	------	------	------	------	------	------	1320. 90	(1296. 67)	1272. 37	1248. 52	(1225. 08)	1201. 55				
$\bar{1},1$ $\bar{1},\bar{1}$	15 16	------	------	------	------	------	------	------	------	1305. 60	1281. 22	(1257. 1)	1233. 31	1209. 79				
$\bar{1},1$ $\bar{1}\ \bar{1}$	17 18	------	------	------	------	------	------	------	------	------	1292. 40	(1268. 4)						

TABLE 4. *Lines in the* $R_{3,\bar{1}}$, $R_{3,\bar{3}}$, $R_{5,3}$, *and* $R_{5,\bar{5}}$ *branches, pure rotation*

Branch	$(J+\tau)''$	$J''=6$	7	8	9	10	11	12	13	14	15	16	17
$3,\bar{1}$	0	370. 16	419. 98	472. 54	526. 08	580. 7	635. 3	(690. 3)	(744. 1)	799. 11	852. 91	906. 32	959. 33
$3,\bar{3}$	1	484. 05	545. 55	(616. 4)	(696. 7)	784. 54	878. 61	976. 07					
$3,\bar{1}$	2	385. 06	418. 57	(457. 9)	502. 31	550. 18	599. 82	(650. 5)	(703. 0)	(756)	808. 14	859. 78	910. 77
$3,\bar{3}$	3	506. 96	546. 50	592. 0	(644. 7)	(705. 5)	775. 63	854. 66	941. 12				
$3,\bar{1}$	4	(457. 0)	(472. 5)	492. 08	517. 00	547. 89	574. 74	(625. 3)	(672. 5)	(726)	(784. 54)	840. 36	
$3,\bar{3}$	5	566. 9	594. 5	625. 25	(659. 2)	(696. 6)	(742. 6)	794. 01	853. 41	921. 48			
$3,\bar{1}$	6	554. 82	569. 2	(580. 7)	(592. 0)	605. 0	620. 7	(641. 4)	(669. 6)	(707)			
$3,\bar{3}$	7	(638. 1)	(663. 0)	(688. 0)	(713. 5)	(740. 7)	770. 17	803. 60	841. 16	883. 18			
$3,\bar{1}$	8	(637. 2)	(659. 4)	(678. 9)	(694. 0)	(705. 2)	(713. 0)	(721. 5)	(730. 8)	(741)			
$3,\bar{3}$	9	------	(729. 4)	(754. 8)	779. 36	803. 09	827. 80	(852. 62)	878. 9	906. 8			
$3,\bar{1}$	10	------	(729. 2)	(754. 0)	777. 07	797. 65	814. 61	827. 21	835. 64	(841. 1)			
$3,\bar{3}$	11	------	------	813. 97	840. 01	865. 51	890. 14	914. 06	937. 40	960. 77			
$3,\bar{1}$	12	------	------	813. 97	840. 01	865. 02	888. 71	910. 17	929. 00				
$3,\bar{3}$ $3,\bar{1}$	13 14	------	------	------	891. 33	918. 52	944. 95	970. 66					
$3,\bar{3}$ $3,\bar{1}$	15 16	------	------	------	------	962. 05	990. 3						
$5,\bar{3}$	0	(613. 0)	(668. 9)	(731. 0)	798. 75	871. 36	948. 35	(1028. 5)					
$5,\bar{3}$	2	(673. 5)	(707. 4)	(748. 5)	796. 01	849. 69	909. 02	973. 59	1042. 57				
$5,\bar{3}$	4	792. 2	808. 33	827. 80	852. 62	883. 89	922. 19	967. 00	1017. 9				
$5,\bar{3}$	6	------	946. 73	959. 78	971. 43	984. 2	1000. 35	1022. 0					
$5,\bar{5}$	1	769. 1	825. 24	887. 33	955. 32	1029. 69							
$5,\bar{5}$	3	841. 97	881. 15	925. 05	974. 04	1028. 47	1088. 1						

TABLE 5. *Rotational constants for* ν_2 *of* H_2O

$v_1v_2v_3$	Constant					
	A	B	C	D_A	D_B	D_C
	cm^{-1}	cm^{-1}	cm^{-1}	$10^{-4}cm^{-1}$	$10^{-4}cm^{-1}$	$10^{-4}cm^{-1}$
010	31. 12	14. 66	9. 15	56. 7	2. 6	0. 4
000	27. 877	14. 512	9. 285	33. 7	2. 39	. 25

WASHINGTON, November 9, 1951.