Microwave Spectra of Molecules of Astrophysical Interest: IV. Hydrogen Sulfide

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Microwave Spectra of Molecules of Astrophysical Interest
IV. Hydrogen Sulfide*

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The available data on the microwave spectrum of hydrogen sulfide are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion constants, hyperfine coupling parameters, and dipole moments are tabulated. A detailed centrifugal distortion calculation has been carried out for the most abundant isotopic form of this molecule, $H_2^{32}S$, as well as for $HD^{32}S$. Transitions have been predicted and tabulated for the frequency range 1 MHz to 1000 GHz for $H_2^{32}S$ and 1 MHz to 700 GHz for $HD^{32}S$. All predicted transitions include 95 percent confidence limits; estimated error limits have been reported for all measured transitions. Observed transitions of $H_2^{33}S$ and $H_2^{34}S$ are also listed.

Key words: Hyperfine structure; hydrogen sulfide; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions.

Contents

1. Introduction

The present tables represent the 4th part of a series of critical reviews [1–3] [1] which are intended to update and revise the existing tabulated literature on molecules already identified in interstellar observations. All of the transitions of $H_2^{32}S$ below 800 GHz which have significant strength in absorption have been observed in the laboratory. Of these only two fall below 100 GHz and none below 30 GHz. In addition to the 39 observed $H_2^{32}S$ transitions [4], all transitions whose lower energy state is below 500 cm^{-1}, whose transition frequency is below 1000 GHz, and whose line strength is at least 0.001 are included in the table of predicted transitions. Unlike $H_2^{32}S$, $HD^{32}S$ has a large number of lines at lower frequencies which are within the range of existing radio telescopes. Several of these transitions would appear to be astrophysically more favorable than a number of the $H_2^{32}S$ transitions included in this review. Since the radio astronomy of interstellar molecules is a rapidly developing field, $HD^{32}S$ is also included in this review although the cosmic abundance of deuterium is expected to be low. In addition to the 45 transitions of $HD^{32}S$ that have been observed in the laboratory [5], all transitions whose lower state energy is below 500 cm^{-1}, and whose transition frequency is between 1 MHz and 700 GHz, are included in the table of predicted transitions. It is felt that these limits are generous enough to allow for the presentation of all transitions that might be observed by existing telescopes or by those likely to be developed in the next several years. Although no analysis of $H_2^{33}S$ or $H_2^{34}S$ has been done, several lines of these species have been identified and measured [6, 7]. These lines are also listed in this review.

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[1] Figures in brackets indicate literature references in section 1.4.

1.1. Molecular Parameter Tables

The rotational constants and centrifugal distortion constants shown in table 1 for $H_2{}^{32}S$ and table 2 for $HD^{32}S$ were obtained from a least-squares analysis of the observed spectral lines with a computer program which includes centrifugal distortion terms in addition to the basic rigid asymmetric rotor energy matrix. Details of the centrifugal distortion calculation and the statistical analysis used in this review have been discussed by Cook, Helminger, and De Lucia [4, 5, 8, 9]. This formulation is similar to ones discussed by Kirchhoff [10] and by Steenbeckeliers [11]. Relations among these formulations are discussed in reference [9]. All analyses are performed in the semi-rigid rotor basis [9]. As pointed out in an earlier part of this series [1–3], it is necessary to retain more significant figures in the spectral constants than indicated by the statistical error limits if the constants are to reproduce the observed spectra to within experimental error. This is particularly true for light molecules such as hydrogen sulfide.

1.2. Microwave Spectral Tables

Tables 3 and 4 contain the results of the statistical analysis of the spectrum of $H_2^{32}S$ and $HD^{32}S$, respectively. For each spectral line the first column of each table contains the upper state and lower state quantum numbers in the form, $J(K_p, K_o)$ for a rigid asymmetric rotor. The quantum numbers are followed by the observed line frequency and, in parentheses, the estimated experimental uncertainty in MHz. The third column contains the calculated frequency and estimated uncertainty in MHz. The calculated uncertainties represent 95 percent confidence levels, which are approximately twice (this varies slightly with the amount of data included in the calculation) the standard deviation obtained from the least squares analysis.

It should be pointed out that the rotation-distortion analysis of asymmetric molecules with large rotational constants is somewhat less straightforward than the analysis of heavier molecules. It is clear that as more transitions at higher J are added to the analysis, more terms must also be added to the Hamiltonian. A corollary of this is that the statistical uncertainty of a transition beyond the range of the observed data set may be unrealistically small because the uncertainties in these additional terms in the Hamiltonian would contribute additional unaccounted error to the calculated uncertainty. This problem is more severe in $H_2^{32}S$ than in HDS. The problem is unlikely to be important in radio astronomy, because virtually all of the lines of $H_2^{32}S$ which are likely to be observed astrophysically have been observed in the laboratory. This is also true for $HD^{32}S$ except for a series of lines at relatively low frequency which are believed to be well predicted. This problem is considered in more detail in references [5, 8, 9].

The line strengths for the unsplit rotational transitions are shown in brackets in column 4. These line strengths, denoted by ${}^{x}S(J'_{K'_p,K'_o};\ J''_{K''_p,K''_o})$, are defined in this review as:

$${}^{x}S(J'_{K'_p,K'_o};\ J''_{K''_p,K''_o}) = \frac{(2J'+1)\,|\mu_{J'\leftarrow J''}|^2}{\mu_x^2}$$

where the superscript x refers to one of the principal axes of the molecule ($x=a, b$ or c); $|\mu_{J'\leftarrow J''}|$ is the dipole moment matrix element connecting the upper, $J'_{K'_p,K'_o}$, and lower, $J''_{K''_p,K''_o}$, rotational levels involved in the transition; and μ_x is the magnitude of the component of μ along the x axis. Thus, the line strength as defined is independent of the absolute magnitude of the dipole moment. Since in the case of $H_2^{32}S$ the two hydrogens are identical particles, the statistical weight of each rotational state must be considered in any calculation of spectral line strengths. States for which the K_p, K_o subscripts are both even (ee) or both odd (oo) have statistical weight one, while the remaining states have statistical weight three. These factors are not included in the tabulated strengths.

The total rotational energy of each rotational level was calculated using all distortion constants which were used in the analysis. These energies are given in column 5 in cm^{-1}. References to the laboratory measurements are shown in the last column of the table.

Table 5 lists observed transitions of $H_2^{33}S$ and $H_2^{34}S$. Although it is not possible to analyze these isotopic species in the above manner because of the limited number of laboratory measurements, these transitions would appear to be prime candidates for astrophysical observation.

Both $H_2^{32}S$ [12, 13] and $HD^{32}S$ [14] have small splittings due to the nuclear moments of hydrogen and deuterium. Since the splittings are rather small and their calculation somewhat complex, these splittings have not been included in tables 3 and 4. They can, however, be calculated [15] from the data in table 6. If these calculations are required for the positive identification of an astrophysical observation, the authors of this review possess the necessary programs.

As a convenience to the user, the calculated unsplit transition frequencies from tables 3 and 4 have been listed according to increasing frequency in tables 7 and 8.

1.3. List of Symbols and Conversion Factors

a. Symbols

A, B, C	Rotational constants (MHz). $A \geq B \geq C$. These correspond to $\mathscr{A}$, $\mathscr{B}$, $\mathscr{C}$ in references [4, 5, 8, and 9].
Δ	Quartic centrifugal distortion constants (MHz).
H, h	Sextic centrifugal distortion constants (MHz).
L, l	Octic centrifugal distortion constants (MHz).
P, p	Decic centrifugal distortion constants (MHz).

a, b, c Principal axes corresponding to A, B, and C, respectively.

μ Dipole moment (Debye).

χ_{ij} Elements of the quadrupole coupling tensor (MHz).

Λ_{ij} Elements of the spin-rotation tensor (dimensionless).

$I_{a,b,c}$ Moments of inertia of whole molecule with respect to the indicated principal axis.

F Total angular momentum quantum number which includes the nuclear spin for the ^{33}S coupling.

J Total rotational angular momentum quantum number.

K_p Projection of J on the symmetry axis in the limiting prolate symmetric top.

K_o Projection of J on the symmetry axis in the limiting oblate symmetric top.

b. Conversion Factors

The following conversion factors have been used:

$$A, B, C\ (\text{MHz}) = \frac{5.05376 \times 10^5}{I_{a,b,c}(\text{amu Å}^2)}$$

$$1\ \text{cm}^{-1} = 29{,}979.25\ \text{MHz}$$

In an attempt to increase the usefulness of this series, the format of the earlier contributions to this series by William H. Kirchhoff, Donald R. Johnson, and Frank J. Lovas of the National Bureau of Standards has been followed whenever possible.

1.4. References

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2. Hydrogen Sulfide Spectral Tables

TABLE 1. Molecular parameters for $H_2^{32}S$

Rotational constants (MHz)	Ref. [72B]
A	310 182.24 ± 0.60
B	270 884.05 ± 0.51
C	141 705.88 ± 0.51
I_c–I_a–I_b (Amu Å^2)	0.07143
Distortion constants (MHz)	**Ref. [72B]**
Δ_J	49.85131 ± 0.038
Δ_{JK}	− 159.69566 ± 0.069
Δ_K	111.8505 ± 0.068
δ_J	− 6.01908 ± 0.0050
δ_K	262.1654 ± 0.21
H_J	(2.81317 ± 0.105) × 10^{-2}
H_{JK}	(− 2.282819 ± 0.027) × 10^{-1}
H_{KJ}	(4.594148 ± 0.16) × 10^{-1}
H_K	(− 2.76462 ± 0.141) × 10^{-1}
h_J	(− 5.8411 ± 0.081) × 10^{-3}
h_{JK}	(2.42811 ± 0.052) × 10^{-1}
h_K	(2.870195 ± 0.039) × 10^{0}
L_{KKJ}	(2.19929 ± 1.19) × 10^{-3}
L_K	(− 2.34287 ± 1.26) × 10^{-3}
l_{KJ}	(− 5.32671 ± 0.99) × 10^{-3}
l_K	(− 4.164750 ± 0.19) × 10^{-2}
P_{KJ}	(− 3.040037 ± 0.70) × 10^{-4}
P_{KKJ}	(8.034210 ± 1.8) × 10^{-4}
P_K	(− 5.152582 ± 1.14) × 10^{-4}
p_{JK}	(− 1.2260 ± 0.52) × 10^{-5}
p_{KKJ}	(1.29628 ± 0.133) × 10^{-4}
Dipole moment (Debye)	**Ref. [65A]**
μ	0.974 ± 0.005

TABLE 2. *Molecular parameters for $HD^{32}S$*

Rotational constants (MHz)	Ref. [71C]
A	292 351.302 ± 0.135
B	147 861.801 ± 0.054
C	96 704.120 ± 0.054
I_c–I_a–I_b (Amu Å^2)	0.07945
Distortion constants (MHz)	**Ref. [71C]**
Δ_J	2.61341 ± 0.0015
Δ_{JK}	28.6933 ± 0.0097
Δ_K	− 11.2972 ± 0.019
δ_J	0.855403 ± 0.00077
δ_K	19.4078 ± 0.0085
H_{JK}	(1.3266 ± 0.044) × 10^{-2}
H_{KJ}	(− 2.028 ± 0.096) × 10^{-2}
H_K	(1.304 ± 0.104) × 10^{-2}
h_J	(1.069 ± 0.22) × 10^{-4}
h_{JK}	(5.3237 ± 0.41) × 10^{-3}
h_K	(2.8365 ± 0.134) × 10^{-2}
Dipole moment (Debye)	**Ref. [51A]**
μ	1.02 ± 0.02

TABLE 3. The microwave spectrum of $H_2^{32}S$. Frequencies are in MHz units.

Transition		Observed frequency (estimated uncertainty)[a]	Calculated frequency (estimated uncertainty)[b]	Line strength	Energy levels[c] in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
1(1, 0)	1(0, 1)	168 762.762373(0.000020)	168 762.782(0.382)	[1.500]	19.376	13.746	68A
1(1, 1)	0(0, 0)	452 390.330(0.034)	452 389.912(0.537)	[1.000]	15.090	0.0	72B
2(2, 0)	2(1, 1)	216 710.4365(0.0015)	216 710.385(0.311)	[2.140]	58.369	51.140	71A
2(2, 1)	2(1, 2)	505 565.230(0.056)	505 564.840(0.505)	[0.833]	55.162	38.298	72B
2(1, 1)	2(0, 2)	393 450.490(0.016)	393 450.541(0.535)	[1.194]	51.140	38.016	72B
2(0, 2)	1(1, 1)	687 303.480(0.379)	687 303.843(0.520)	[1.284]	38.016	15.090	72B
2(1, 2)	1(0, 1)	736 033.650(0.894)	736 033.800(0.492)	[1.500]	38.298	13.746	72B
3(3, 0)	3(2, 1)	300 505.560(0.100)	300 505.583(0.409)	[3.007]	117.392	107.368	68A
3(3, 1)	3(2, 2)	568 050.550(0.046)	568 050.748(0.414)	[1.310]	115.341	96.392	72B
3(2, 1)	3(1, 2)	369 101.450(0.009)	369 101.207(0.505)	[0.130]	107.368	95.056	72B
3(2, 2)	3(1, 3)	747 301.890(0.445)	747 301.537(0.582)	[1.023]	96.392	71.465	72B
3(1, 2)	3(0, 3)	708 470.430(0.406)	708 470.778(0.571)	[1.525]	95.056	71.424	72B
3(1, 3)	2(2, 0)	392 617.840(0.067)	392 617.541(0.748)	[0.008]	71.465	58.369	72B
3(0, 3)	2(1, 2)		993 108.465(0.957)	[1.459]	71.424	38.298	
4(4, 0)	4(3, 1)	424 314.820(0.035)	424 315.039(0.480)	[2.246]	196.802	182.648	72B
4(4, 1)	4(3, 2)	650 374.470(0.396)	650 375.058(0.480)	[1.765]	195.661	173.967	72B
4(3, 1)	4(2, 2)	369 126.912(0.100)	369 126.720(0.527)	[3.562]	182.648	170.336	68A
4(3, 2)	4(2, 3)	765 937.910(0.651)	765 938.373(0.629)	[0.009]	173.967	148.418	72B
4(2, 2)	4(1, 3)	665 393.700(0.251)	665 393.353(0.569)	[2.064]	170.336	148.141	72B
4(2, 3)	3(3, 0)		930 145.621(1.170)	[0.078]	148.418	117.392	
3(3, 1)	4(0, 4)	35 028.150	35 027.952(0.644)	[0.001]	115.341	114.172	72B
4(1, 4)	3(2, 1)	204 140.170(0.018)	204 140.037(0.644)	[0.000]	114.178	107.368	72B
5(5, 0)	5(4, 1)	579 799.000(0.132)	579 798.605(0.691)	[3.120]	296.678	277.338	72B
5(5, 1)	5(4, 2)	749 432.280(0.447)	749 431.962(0.680)	[1.746]	296.105	271.106	72B
5(4, 1)	5(3, 2)	407 676.730(0.024)	407 676.843(0.550)	[0.241]	277.338	263.739	72B
5(4, 2)	5(3, 3)		800 855.957(1.629)	[2.461]	271.106	244.393	
5(3, 2)	5(2, 3)	611 441.630(0.079)	611 441.431(0.610)	[4.844]	263.739	243.344	72B
5(2, 3)	5(1, 4)		993 100.362(4.712)	[0.030]	243.344	210.217	
5(1, 4)	4(4, 1)	436 373.360(0.283)	436 373.382(0.806)	[0.001]	210.217	195.661	72B
5(2, 4)	4(3, 1)		827 915.490(0.979)	[0.012]	210.265	182.648	
4(3, 2)	5(0, 5)	228 556.270(0.024)	228 556.227(0.633)	[0.001]	173.967	166.343	72B
4(2, 2)	5(1, 5)	119 664.420(0.015)	119 664.468(0.633)	[0.001]	170.336	166.344	72B
6(6, 0)	6(5, 1)	748 241.490(0.377)	748 241.663(0.797)	[1.951]	416.847	391.888	72B
6(6, 1)	6(5, 2)		860 129.546(2.303)	[1.966]	416.577	387.886	
6(5, 1)	6(4, 2)	493 362.160(0.072)	493 362.164(0.612)	[4.498]	391.888	375.432	72B
6(5, 2)	6(4, 3)		854 974.897(3.795)	[0.001]	387.886	359.367	
6(4, 2)	6(3, 3)	567 079.480(0.033)	567 079.561(0.640)	[4.529]	375.432	356.516	72B
6(3, 3)	6(2, 4)		947 265.873(17.350)	[2.979]	356.516	324.918	
6(2, 4)	5(5, 1)		863 817.101(28.360)	[0.004]	324.918	296.105	
6(1, 5)	5(4, 2)	314 437.790(0.182)	314 437.779(0.810)	[0.002]	281.595	271.106	72B
6(2, 5)	5(3, 2)		535 531.825(1.554)	[0.005]	281.602	263.739	
7(6, 1)	7(5, 2)	626 474.550(0.192)	626 474.547(0.795)	[0.010]	526.656	505.759	72B
7(6, 2)	7(5, 3)		928 657.767(4.648)	[3.242]	524.348	493.371	
7(5, 2)	7(4, 3)	555 254.030(0.054)	555 254.039(0.748)	[7.522]	505.759	487.238	72B
7(4, 3)	7(3, 4)		880 073.156(46.690)	[0.159]	487.238	457.882	
7(2, 5)	6(5, 2)		827 192.508(166.080)	[0.009]	415.478	387.886	
7(1, 6)	6(4, 3)	89 497.990(0.026)	89 498.149(0.793)	[0.001]	362.352	359.367	72B
7(2, 6)	6(3, 3)	175 009.580(0.019)	175 009.422(0.795)	[0.002]	362.353	356.516	72B
8(6, 2)	8(5, 3)	593 170.230(0.133)	593 170.226(0.804)	[6.450]	655.201	635.415	72B
8(2, 6)	7(5, 3)		656 883.103(709.960)	[0.003]	515.282	493.371	
8(3, 6)	7(4, 3)		841 015.915(716.350)	[0.003]	515.291	487.238	
7(4, 4)	8(1, 7)	185 099.880(0,023)	185 100.018(0.800)	[0.001]	458.671	452.496	72B
7(3, 4)	8(2, 7)	161 438.450(0.027)	161 438.312(0.800)	[0.001]	457.882	452.497	72B
9(7, 2)	9(6, 3)	689 120.170(0.328)	689 120.168(0.812)	[7.886]	824.285	801.298	72B

[a] For reference [72B], the estimated experimental uncertainties are the run's deviations of 5 or more measurements of each line frequency and include no correction for possible systematic effects. These may be particularly useful in identifying lines which were difficult to measure because of low signal-to-noise ratio. For all other references, the values are those quoted by the author.

[b] See text.

[c] In keeping with the common convention in molecular spectroscopy, energies are expressed in their wavenumber (cm^{-1}) equivalents. The actual energy may be obtained by multiplying the wavenumber values by the product of Planck's constant and the speed of light expressed in centimeters per second.

TABLE 4. The microwave spectrum of $HD^{32}S$

Transition		Observed frequency (estimated uncertainty)[a]	Calculated frequency (estimated uncertainty)[b]	Line strength	Energy levels[c] in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
1(1, 0)	1(1, 1)	51 073.270	51 073.365(0.053)	[1.500]	14.681	12.977	51A
1(0, 1)	0(0, 0)	244 555.580	244 555.467(0.086)	[1.000]	8.157	0.0	70A
1(1, 0)	1(0, 1)	195 558.920	195 558.960(0.120)	[1.500]	14.681	8.157	70A
1(1, 1)	0(0, 0)	389 041.080(0.033)	389 041.062(0.149)	[1.000]	12.977	0.0	71C
2(1, 1)	2(1, 2)	153 179.160	153 179.332(0.131)	[0.833]	32.693	27.583	70A
2(2, 1)	2(0, 2)		691 050.292(0.298)	[0.054]	47.145	24.094	
2(2, 0)	2(2, 1)	11 283.830	11 284.012(0.029)	[3.280]	47.521	47.145	51A
2(0, 2)	1(0, 1)	477 764.270(0.049)	477 764.200(0.143)	[1.968]	24.094	8.157	71C
2(1, 2)	1(1, 1)	437 880.830(0.038)	437 880.798(0.141)	[1.500]	27.583	12.977	71C
2(1, 1)	1(1, 0)	539 986.650(0.041)	539 986.765(0.145)	[1.500]	32.693	14.681	71C
2(1, 1)	2(0, 2)	257 781.410	257 781.526(0.129)	[2.110]	32.693	24.094	70A
2(2, 1)	2(1, 2)		586 448.098(0.233)	[0.833]	47.145	27.583	
2(2, 0)	2(1, 1)	444 552.850(0.020)	444 552.778(0.204)	[1.223]	47.521	32.693	71C
2(1, 2)	1(0, 1)	582 366.420(0.044)	582 366.393(0.188)	[1.500]	27.583	8.157	71C
2(0, 2)	1(1, 1)	333 278.710	333 278.604(0.159)	[0.734]	24.094	12.977	70A
3(1, 2)	3(1, 3)	304 640.540	304 640.469(0.194)	[0.595]	59.438	49.277	70A
3(2, 1)	3(2, 2)	53 200.930	53 201.012(0.092)	[2.175]	73.361	71.586	51A
3(3, 0)	3(3, 1)		1 596.061(0.010)	[5.212]	100.183	100.130	
3(0, 3)	2(0, 2)		691 498.513(0.176)	[2.895]	47.160	24.094	
2(2, 0)	3(0, 3)		10 835.791(0.259)	[0.015]	47.521	47.160	
3(1, 3)	2(1, 2)		650 358.149(0.165)	[2.656]	49.277	27.583	
3(1, 2)	3(0, 3)	368 102.220(0.017)	368 102.299(0.163)	[2.271]	59.438	47.160	71C
3(2, 2)	3(1, 3)		668 820.606(0.226)	[1.310]	71.586	49.277	
3(2, 1)	3(1, 2)	417 381.100(0.015)	417 381.149(0.178)	[2.479]	73.361	59.438	71C
3(0, 3)	2(1, 2)	586 896.200(0.135)	586 896.320(0.178)	[1.694]	47.160	27.583	71C
3(1, 3)	2(2, 0)		52 626.039(0.243)	[0.107]	49.277	47.521	
3(1, 2)	2(2, 1)	368 550.520(0.029)	368 550.520(0.218)	[0.286]	59.438	47.145	71C
4(1, 3)	4(1, 4)		499 262.129(0.249)	[0.488]	94.518	77.864	
4(2, 2)	4(2, 3)	143 034.720(0.019)	143 034.823(0.151)	[1.545]	108.647	103.876	71C
4(3, 1)	4(3, 2)	10 861.070	10 861.157(0.051)	[3.925]	133.646	133.284	51A
4(4, 0)	4(4, 1)		184.781(0.004)	[7.168]	172.396	172.390	
4(0, 4)	3(2, 1)		102 092.610(0.221)	[0.028]	76.766	73.361	
3(3, 1)	4(1, 4)		667 496.447(0.417)	[0.001]	100.130	77.864	
3(3, 0)	4(1, 3)		169 830.379(0.374)	[0.006]	100.183	94.518	
4(1, 3)	4(0, 4)	532 187.040(0.068)	532 186.810(0.212)	[2.149]	94.518	76.766	71C
4(2, 2)	4(1, 3)	423 571.360(0.029)	423 571.507(0.214)	[3.635]	108.647	94.518	71C
4(1, 4)	3(2, 1)	135 017.270(0.057)	135 017.291(0.200)	[0.136]	77.864	73.361	71C
4(1, 3)	3(2, 2)		687 480.432(0.251)	[0.784]	94.518	71.586	
4(2, 3)	3(3, 0)	110 706.220(0.023)	110 706.305(0.298)	[0.131]	103.876	100.183	71C
4(2, 2)	3(3, 1)		255 337.189(0.319)	[0.155]	108.647	100.130	
5(2, 3)	5(2, 4)		286 920.914(0.184)	[1.163]	153.341	143.770	
5(3, 2)	5(3, 3)	40 929.200	40 929.208(0.116)	[3.042]	176.149	174.784	51A
5(4, 1)	5(4, 2)		1 636.816(0.022)	[5.766]	213.852	213.798	
5(5, 0)	5(5, 1)		19.100(0.001)	[9.138]	263.978	263.978	
5(0, 5)	4(2, 2)		120 426.455(0.374)	[0.025]	112.664	108.647	
4(3, 2)	5(1, 5)		602 940.086(0.621)	[0.003]	133.284	113.172	
5(1, 4)	4(3, 1)		109 928.538(0.384)	[0.024]	137.313	133.646	
4(4, 0)	5(2, 3)		571 260.976(0.625)	[0.002]	172.396	153.341	
5(2, 3)	5(1, 4)	480 508.880(0.058)	480 508.895(0.233)	[4.326]	153.341	137.313	71C
5(3, 2)	5(2, 3)		683 761.621(0.602)	[3.309]	176.149	153.341	
5(1, 5)	4(2, 2)	135 654.990(0.028)	135 654.927(0.368)	[0.105]	113.172	108.647	71C
4(3, 2)	5(0, 5)		618 168.558(0.602)	[0.011]	133.284	122.664	
5(2, 4)	4(3, 1)	303 516.540(0.027)	303 516.518(0.261)	[0.269]	143.770	133.646	71C
5(2, 3)	4(3, 2)		601 298.589(0.294)	[0.410]	153.341	133.284	
5(3, 3)	4(4, 0)		71 571.437(0.408)	[0.114]	174.784	172.396	
5(3, 2)	4(4, 1)	112 685.450(0.043)	112 685.426(0.388)	[0.116]	176.149	172.390	71C
6(2, 4)	6(2, 5)	480 983.250(0.082)	480 983.223(0.259)	[0.940]	207.039	190.996	71C
6(3, 3)	6(3, 4)	110 281.150(0.021)	110 280.760(0.176)	[2.362]	228.190	224.512	71C
6(4, 2)	6(4, 3)	7 936.740	7 396.731(0.069)	[4.753]	263.963	263.698	51A
6(5, 1)	6(5, 2)		208.200(0.008)	[7.650]	313.492	313.485	
6(6, 0)	6(6, 1)		1.827(0.000)	[11.117]	374.831	374.831	
6(0, 6)	5(2, 3)		45 306.341(1.115)	[0.017]	154.852	153.341	
5(3, 3)	6(1, 6)		591 009.270(1.393)	[0.005]	174.784	155.070	

TABLE 4. The microwave spectrum of $HD^{32}S$—Continued

Transition		Observed frequency (estimated uncertainty)[a]	Calculated frequency (estimated uncertainty)[b]	Line strength	Energy levels[c] in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
6(1, 5)	5(3, 2)		327 272.767(0.513)	[0.050]	187.065	176.149	
5(4, 2)	6(2, 5)		683 597.023(0.796)	[0.004]	213.798	190.996	
5(4, 1)	6(2, 4)		204 250.615(0.737)	[0.009]	213.852	207.039	
6(2, 4)	6(1, 5)	598 805.170(0.078)	598 805.121(0.247)	[4.438]	207.039	187.065	71C
6(3, 3)	6(2, 4)		634 088.267(0.509)	[4.703]	228.190	207.039	
6(1, 6)	5(2, 3)		51 823.143(1.135)	[0.067]	155.070	153.341	
5(3, 3)	6(0, 6)		597 526.072(1.362)	[0.017]	174.784	154.852	
6(2, 5)	5(3, 2)	445 094.650(0.051)	445 094.665(0.382)	[0.337]	190.996	176.149	71C
6(3, 4)	5(4, 1)		319 556.891(0.423)	[0.275]	224.512	213.852	
6(3, 3)	5(4, 2)	431 474.460(0.071)	431 474.467(0.388)	[0.292]	228.190	213.798	71C
5(5, 0)	6(4, 3)		8 391.254(3.512)	[0.096]	263.978	263.698	
5(5, 1)	6(4, 2)		435.423(3.512)	[0.096]	263.978	263.963	
7(3, 4)	7(3, 5)		234 044.867(0.243)	[1.837]	290.065	282.259	
7(4, 3)	7(4, 4)	27 566.310	27 565.932(0.137)	[3.947]	323.042	322.122	51A
7(5, 2)	7(5, 3)		1 227.406(0.033)	[6.528]	371.511	371.470	
7(6, 1)	7(6, 2)		23.666(0.002)	[9.562]	432.349	432.348	
6(2, 4)	7(0, 7)		109 478.009(3.145)	[0.011]	207.040	203.388	
6(3, 4)	7(1, 7)		630 644.215(3.431)	[0.005]	224.512	203.476	
7(1, 6)	6(3, 3)		448 753.038(1.609)	[0.064]	243.159	228.190	
6(4, 3)	7(2, 6)		552 192.746(1.119)	[0.008]	263.698	245.279	
7(2, 5)	6(4, 2)		154 523.397(1.139)	[0.025]	269.117	263.963	
7(3, 4)	7(2, 5)	628 018.530(0.049)	628 018.513(0.394)	[5.940]	290.065	269.117	71C
6(2, 4)	7(1, 7)		106 836.708(3.165)	[0.042]	207.039	203.476	
6(3, 4)	7(0, 7)		633 285.515(3.390)	[0.020]	224.512	203.388	
7(2, 6)	6(3, 3)		512 298.409(1.370)	[0.308]	245.279	228.190	
6(4, 3)	7(1, 6)		615 738.118(1.101)	[0.022]	263.698	243.159	
7(3, 5)	6(4, 2)		548 497.043(1.113)	[0.435]	282.259	263.963	
7(4, 4)	6(5, 1)		258 733.873(3.165)	[0.244]	322.122	313.492	
7(4, 3)	6(5, 2)		286 508.005(3.124)	[0.245]	323.042	313.485	
6(6, 0)	7(5, 3)		100 757.330(14.171)	[0.082]	374.831	371.470	
6(6, 1)	7(5, 2)		99 528.097(14.192)	[0.082]	374.831	371.511	
8(3, 5)	8(3, 6)	415 880.030(0.032)	415 880.179(0.304)	[1.467]	361.616	347.744	71C
8(4, 4)	8(4, 5)	75 551.730	75 552.262(0.216)	[3.250]	391.546	389.026	51A
8(5, 3)	8(5, 4)		5 161.090(0.082)	[5.628]	438.190	438.018	
8(6, 2)	8(6, 3)		164.153(0.012)	[8.349]	498.297	498.291	
7(2, 5)	8(0, 8)		324 007.538(8.005)	[0.007]	269.117	258.309	
8(1, 7)	7(3, 4)		458 109.941(3.553)	[0.055]	305.346	290.065	
7(4, 4)	8(2, 7)		471 864.229(2.818)	[0.011]	322.122	306.383	
8(2, 6)	7(4, 3)		471 760.969(3.900)	[0.056]	338.778	323.042	
7(5, 2)	8(3, 5)		296 634.175(5.105)	[0.010]	371.511	361.616	
8(3, 5)	8(2, 6)		684 675.824(0.950)	[6.610]	361.616	338.778	
7(2, 5)	8(1, 8)		322 979.910(8.045)	[0.028]	269.117	258.344	
8(2, 7)	7(3, 4)		489 174.383(3.186)	[0.226]	306.383	290.065	
7(4, 4)	8(1, 7)		502 928.670(3.043)	[0.038]	322.122	305.346	
8(4, 5)	7(5, 2)		525 087.798(4.186)	[0.417]	389.026	371.511	
8(4, 4)	7(5, 3)		601 867.466(4.125)	[0.427]	391.546	371.470	
8(5, 4)	7(6, 1)		169 949.478(12.987)	[0.214]	438.018	432.349	
8(5, 3)	7(6, 2)		175 134.234(12.987)	[0.214]	438.190	432.348	
7(7, 0)	8(6, 3)		196 972.202(39.615)	[0.071]	504.862	498.291	
7(7, 1)	8(6, 2)		196 807.884(39.615)	[0.071]	504.862	498.297	
9(3, 6)	9(3, 7)		648 612.592(0.950)	[1.236]	442.288	420.653	
9(4, 5)	9(4, 6)		170 641.228(0.300)	[2.632]	469.958	464.267	
9(5, 4)	9(5, 5)	17 212.610	17 212.322(0.143)	[4.861]	513.765	513.190	51A
8(2, 6)	9(0, 9)		573 917.077(18.419)	[0.006]	338.778	319.634	
9(1, 8)	8(3, 5)		360 941.257(5.861)	[0.039]	373.656	361.616	
8(4, 5)	9(2, 8)		446 670.109(6.003)	[0.014]	389.026	374.127	
8(5, 4)	9(3, 7)		520 579.465(9.271)	[0.013]	438.018	420.653	
9(3, 6)	8(5, 3)		122 872.037(9.475)	[0.025]	442.288	438.190	
8(2, 6)	9(1, 9)		573 530.264(18.460)	[0.021]	338.778	319.647	
9(2, 8)	8(3, 5)		375 051.864(5.452)	[0.150]	374.127	361.616	
8(4, 5)	9(1, 8)		460 780.716(6.330)	[0.049]	389.026	373.656	
8(5, 4)	9(2, 7)		684 945.221(10.435)	[0.027]	438.018	415.170	

TABLE 4. The microwave spectrum of $HD^{32}S$—Continued

Transition		Observed frequency (estimated uncertainty)[a]	Calculated frequency (estimated uncertainty)[b]	Line strength	Energy levels[c] in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
9(5, 5)	8(6, 2)		446 495.333(13.641)	[0.376]	513.190	498.297	
9(5, 4)	8(6, 3)		463 871.808(13.641)	[0.377]	513.765	498.291	
10(4, 6)	10(4, 7)	326 381.480(0.023)	326 381.421(0.388)	[2.118]	558.492	547.605	71C
10(5, 5)	10(5, 6)	47 905.360	47 905.067(0.214)	[4.167]	598.597	596.999	51A
10(1, 9)	9(3, 6)		176 880.383(8.474)	[0.027]	448.188	442.288	
9(4, 6)	10(2, 9)		475 945.369(10.680)	[0.014]	464.267	448.391	
10(2, 9)	9(3, 6)		182 944.293(8.188)	[0.099]	448.391	442.288	
9(4, 6)	10(1, 9)		482 009.279(10.945)	[0.052]	464.267	448.188	
9(5, 5)	10(2, 8)		465 603.770(19.113)	[0.051]	513.190	497.660	
11(6, 5)	11(6, 6)	10 235.810	10 236.165(0.159)	[5.777]	747.860	747.518	51A
12(6, 6)	12(6, 7)	28 842.840	28 842.908(0.341)	[5.089]	848.926	847.964	51A

[a] The estimated experimental uncertainties are the rms deviations of 5 or more measurements of each line frequency and include no correction for possible systematic effects. These may be particularly useful in identifying lines which were difficult to measure because of low signal-to-noise ratio.

[b] See text.

[c] In keeping with the common convention in molecular spectroscopy, energies are expressed in their wavenumber (cm^{-1}) equivalents. The actual energy may be obtained by multiplying the wavenumber values by the product of Planck's constant and the speed of light expressed in centimeters per second.

TABLE 5. Observed transitions of $H_2^{33}S$ and $H_2^{34}S$

Transition	Frequency in MHz (estimated uncertainty)	Reference
$H_2^{33}S$[a] 1(1, 0)–1(0, 1): $F=5/2–5/2$	168 318.93	53A
$F=3/2–1/2$	168 318.93	53A
$F=1/2–3/2$	168 322.63	53A
$F=3/2–5/2$	168 326.90	53A
$F=5/2–3/2$	168 329.03	53A
$H_2^{34}S$ 1(1, 0)–1(0, 1)	167 910.516(0.002)	71A
2(2, 0)–2(1, 1)	213 376.9236(0.002)	71A

[a] The transitions of $H_2^{33}S$ are split by a quadrupole interaction of the ^{33}S nucleus (spin 3/2). The quadrupole coupling constants of $H_2^{33}S$ are listed in Ref. [53A].

TABLE 6. Hyperfine coupling constants. Ref. [71B]

Elements of the quadrupole coupling tensor	
χ_{11}	0.0542 ± 0.0019 MHz
χ_{22}	0.0350 ± 0.0014 MHz
χ_{33}	-0.0892 ± 0.0008 MHz
χ_{12}	0.1039 ± 0.0016 MHz
Elements of the spin-rotation tensor	
A_{11}	$(-119\pm13)\times10^{-10}$
A_{22}	$(-74\pm15)\times10^{-10}$
A_{33}	$(-247\pm28)\times10^{-10}$
A_{12}	$(125\pm2)\times10^{-10}$

TABLE 7. Microwave transitions of $H_2^{32}S$ in order of frequency

Frequency (MHz)	Transition	Estimated uncertainty (MHz)	Frequency (MHz)	Transition	Estimated uncertainty (MHz)
35 027.952	3(3, 1)–4(0, 4)	(0.644)	452 389.912	1(1, 1)–0(0, 0)	(0.537)
89 498.149	7(1, 6)–6(4, 3)	(0.793)	493 362.164	6(5, 1)–6(4, 2)	(0.612)
119 664.468	4(2, 2)–5(1, 5)	(0.633)	505 564.840	2(2, 1)–2(1, 2)	(0.505)
161 438.312	7(3, 4)–8(2, 7)	(0.800)	535 531.825	6(2, 5)–5(3, 2)	(1.554)
168 762.782	1(1, 0)–1(0, 1)	(0.382)	555 254.039	7(5, 2)–7(4, 3)	(0.748)
175 009.422	7(2, 6)–6(3, 3)	(0.795)	567 079.561	6(4, 2)–6(3, 3)	(0.640)
185 100.018	7(4, 4)–8(1, 7)	(0.800)	568 050.748	3(3, 1)–3(2, 2)	(0.414)
204 140.037	4(1, 4)–3(2, 1)	(0.644)	579 798.605	5(5, 0)–5(4, 1)	(0.691)
216 710.385	2(2, 0)–2(1, 1)	(0.311)	593 170.226	8(6, 2)–8(5, 3)	(0.804)
228 556.227	4(3, 2)–5(0, 5)	(0.633)	611 441.431	5(3, 2)–5(2, 3)	(0.610)
300 505.583	3(3, 0)–3(2, 1)	(0.409)	626 474.547	7(6, 1)–7(5, 2)	(0.795)
314 437.779	6(1, 5)–5(4, 2)	(0.810)	650 375.058	4(4, 1)–4(3, 2)	(0.480)
369 101.207	3(2, 1)–3(1, 2)	(0.505)	656 883.103	8(2, 6)–7(5, 3)	(709.960)
369 126.720	4(3, 1)–4(2, 2)	(0.527)	665 393.353	4(2, 2)–4(1, 3)	(0.569)
392 617.541	3(1, 3)–2(2, 0)	(0.748)	687 303.843	2(0, 2)–1(1, 1)	(0.520)
393 450.541	2(1, 1)–2(0, 2)	(0.535)	689 120.168	9(7, 2)–9(6, 3)	(0.812)
407 676.843	5(4, 1)–5(3, 2)	(0.550)	708 470.778	3(1, 2)–3(0, 3)	(0.571)
424 315.039	4(4, 0)–4(3, 1)	(0.480)	736 033.800	2(1, 2)–1(0, 1)	(0.492)
436 373.382	5(1, 4)–4(4, 1)	(0.806)	747 301.537	3(2, 2)–3(1, 3)	(0.582)

TABLE 7. Microwave transitions of $H_2^{32}S$ in order of frequency—Continued

Frequency (MHz)	Transition	Estimated uncertainty (MHz)	Frequency (MHz)	Transition	Estimated uncertainty (MHz)
748 241.663	6(6, 0)–6(5, 1)	(0.797)	860 129.546	6(6, 1) 6(5, 2)	(2.303)
749 431.962	5(5, 1)–5(4, 2)	(0.680)	863 817.101	6(2, 4)–5(5, 1)	(28.360)
765 938.373	4(3, 2)–4(2, 3)	(0.629)	880 073.156	7(4, 3)–7(3, 4)	(46.690)
800 855.957	5(4, 2)–5(3, 3)	(1.629)	928 657.767	7(6, 2)–7(5, 3)	(4.648)
827 192.508	7(2, 5)–6(5, 2)	(166.080)	930 145.621	4(2, 3)–3(3, 0)	(1.170)
827 915.490	5(2, 4)–4(3, 1)	(0.979)	947 265.873	6(3, 3)–6(2, 4)	(17.350)
841 015.915	8(3, 6)–7(4, 3)	(716.350)	993 100.362	5(2, 3)–5(1, 4)	(4.712)
854 974.897	6(5, 2)–6(4, 3)	(3.795)	993 108.465	3(0, 3)–2(1, 2)	(0.957)

TABLE 8. Microwave transitions of $HD^{32}S$ in order of frequency

Frequency (MHz)	Transition	Estimated uncertainty (MHz)	Frequency (MHz)	Transition	Estimated uncertainty (MHz)
1.827	6(6, 0)–6(6, 1)	(0.000)	175 134.234	8(5, 3)–7(6, 2)	(12.987)
19.100	5(5, 0)–5(5, 1)	(0.001)	176 880.383	10(1, 9)–9(3, 6)	(8.474)
23.666	7(6, 1)–7(6, 2)	(0.002)	182 944.293	10(2, 9)–9(3, 6)	(8.188)
164.153	8(6, 2)–8(6, 3)	(0.012)	195 558.960	1(1, 0)–1(0, 1)	(0.120)
184.781	4(4, 0)–4(4, 1)	(0.004)	196 807.884	7(7, 1)–8(6, 2)	(39.615)
208.200	6(5, 1)–6(5, 2)	(0.008)	196 972.202	7(7, 0)–8(6, 3)	(39.615)
435.423	5(5, 1)–6(4, 2)	(3.512)	204 250.615	5(4, 1)–6(2, 4)	(0.737)
1 227.406	7(5, 2)–7(5, 3)	(0.033)	234 044.867	7(3, 4)–7(3, 5)	(0.243)
1 596.061	3(3, 0) 3(3, 1)	(0.010)	244 555.467	1(0, 1)–0(0, 0)	(0.006)
1 636.816	5(4, 1)–5(4, 2)	(0.022)	255 337.189	4(2, 2)–3(3, 1)	(0.319)
5 161.090	8(5, 3)–8(5, 4)	(0.082)	257 781.526	2(1, 1)–2(0, 2)	(0.129)
7 936.731	6(4, 2)–6(4, 3)	(0.069)	258 733.873	7(4, 4)–6(5, 1)	(3.165)
8 391.254	5(5, 0)–6(4, 3)	(3.512)	286 508.005	7(4, 3)–6(5, 2)	(3.124)
10 236.165	11(6, 5)–11(6, 6)	(0.159)	286 920.914	5(2, 3)–5(2, 4)	(0.184)
10 835.791	2(2, 0)–3(0, 3)	(0.259)	296 634.175	7(5, 2)–8(3, 5)	(5.105)
10 861.157	4(3, 1)–4(3, 2)	(0.051)	303 516.518	5(2, 4)–4(3, 1)	(0.261)
11 284.012	2(2, 0)–2(2, 1)	(0.029)	304 640.469	3(1, 2)–3(1, 3)	(0.194)
17 212.322	9(5, 4)–9(5, 5)	(0.143)	319 556.891	6(3, 4)–5(4, 1)	(0.423)
27 565.932	7(4, 3)–7(4, 4)	(0.137)	322 979.910	7(2, 5)–8(1, 8)	(8.045)
28 842.908	12(6, 6)–12(6, 7)	(0.341)	324 007.538	7(2, 5)–8(0, 8)	(8.005)
40 929.208	5(3, 2)–5(3, 3)	(0.116)	326 381.421	10(4, 6)–10(4, 7)	(0.388)
45 306.341	6(0, 6)–5(2, 3)	(1.115)	327 272.767	6(1, 5)–5(3, 2)	(0.513)
47 905.067	10(5, 5)–10(5, 6)	(0.214)	333 278.604	2(0, 2)–1(1, 1)	(0.159)
51 073.365	1(1, 0)–1(1, 1)	(0.053)	360 941.257	9(1, 8)–8(3, 5)	(5.861)
51 823.143	6(1, 6)–5(2, 3)	(1.135)	368 102.299	3(1, 2)–3(0, 3)	(0.163)
52 626.039	3(1, 3)–2(2, 0)	(0.243)	368 550.520	3(1, 2)–2(2, 1)	(0.218)
53 201.012	3(2, 1)–3(2, 2)	(0.092)	375 051.864	9(2, 8)–8(3, 5)	(5.452)
71 571.437	5(3, 3)–4(4, 0)	(0.408)	389 041.062	1(1, 1)–0(0, 0)	(0.149)
75 552.262	8(4, 4)–8(4, 5)	(0.216)	415 880.179	8(3, 5)–8(3, 6)	(0.304)
99 528.097	6(6, 1)–7(5, 2)	(14.192)	417 381.149	3(2, 1)–3(1, 2)	(0.178)
100 757.330	6(6, 0)–7(5, 3)	(14.171)	423 571.507	4(2, 2)–4(1, 3)	(0.214)
102 092.610	4(0, 4)–3(2, 1)	(0.221)	431 474.467	6(3, 3)–5(4, 2)	(0.388)
106 836.708	6(2, 4)–7(1, 7)	(3.165)	437 880.798	2(1, 2)–1(1, 1)	(0.141)
109 478.009	6(2, 4)–7(0, 7)	(3.145)	444 552.778	2(2, 0)–2(1, 1)	(0.204)
109 928.538	5(1, 4)–4(3, 1)	(0.384)	445 094.665	6(2, 5)–5(3, 2)	(0.382)
110 280.760	6(3, 3)–6(3, 4)	(0.176)	446 495.333	9(5, 5)–8(6, 2)	(13.641)
110 706.305	4(2, 3)–3(3, 0)	(0.298)	446 670.109	8(4, 5)–9(2, 8)	(6.003)
112 685.426	5(3, 2)–4(4, 1)	(0.388)	448 753.038	7(1, 6)–6(3, 3)	(1.609)
120 426.455	5(0, 5)–4(2, 2)	(0.374)	458 109.941	8(1, 7)–7(3, 4)	(3.553)
122 872.037	9(3, 6)–8(5, 3)	(9.475)	460 780.716	8(4, 5)–9(1, 8)	(6.330)
135 017.291	4(1, 4)–3(2, 1)	(0.200)	463 871.808	9(5, 4)–8(6, 3)	(13.641)
135 654.927	5(1, 5)–4(2, 2)	(0.368)	465 603.770	9(5, 5)–10(2, 8)	(19.113)
143 034.823	4(2, 2)–4(2, 3)	(0.151)	471 760.969	8(2, 6)–7(4, 3)	(3.900)
153 179.332	2(1, 1)–2(1, 2)	(0.131)	471 864.229	7(4, 4)–8(2, 7)	(2.818)
154 523.397	7(2, 5)–6(4, 2)	(1.139)	475 945.369	9(4, 6)–10(2, 9)	(10.680)
169 830.379	3(3, 0)–4(1, 3)	(0.374)	477 764.200	2(0, 2)–1(0, 1)	(0.143)
169 949.478	8(5, 4)–7(6, 1)	(12.987)	480 508.895	5(2, 3)–5(1, 4)	(0.233)
170 641.228	9(4, 5)–9(4, 6)	(0.300)	480 983.223	6(2, 4)–6(2, 5)	(0.259)

TABLE 8. Microwave transitions of $HD^{32}S$ in order of frequency—Continued

Frequency (MHz)	Transition	Estimated uncertainty (MHz)	Frequency (MHz)	Transition	Estimated uncertainty (MHz)
482 009.279	9(4, 6)–10(1, 9)	(10.945)	601 298.509	5(2, 3)–4(3, 2)	(0.294)
489 174.383	8(2, 7)–7(3, 4)	(3.186)	601 867.466	8(4, 4)–7(5, 3)	(4.125)
499 262.129	4(1, 3)–4(1, 4)	(0.249)	602 940.086	4(3, 2)–5(1, 5)	(0.621)
502 928.670	7(4, 4)–8(1, 7)	(3.043)	615 738.118	6(4, 3)–7(1, 6)	(1.101)
512 298.409	7(2, 6)–6(3, 3)	(1.370)	618 168.558	4(3, 2)–5(0, 5)	(0.602)
520 579.465	8(5, 4)–9(3, 7)	(9.271)	628 018.513	7(3, 4)–7(2, 5)	(0.394)
525 087.798	8(4, 5)–7(5, 2)	(4.186)	630 644.215	6(3, 4)–7(1, 7)	(3.431)
532 186.810	4(1, 3)–4(0, 4)	(0.212)	633 285.515	6(3, 4)–7(0, 7)	(3.390)
539 986.765	2(1, 1)–1(1, 0)	(0.145)	634 088.267	6(3, 3)–6(2, 4)	(0.509)
548 497.043	7(3, 5)–6(4, 2)	(1.113)	648 612.592	9(3, 6)–9(3, 7)	(0.950)
552 192.746	6(4, 3)–7(2, 6)	(1.119)	650 358.149	3(1, 3)–2(1, 2)	(0.165)
571 260.976	4(4, 0)–5(2, 3)	(0.625)	667 496.447	3(3, 1)–4(1, 4)	(0.417)
573 530.264	8(2, 6)–9(1, 9)	(18.460)	668 820.606	3(2, 2)–3(1, 3)	(0.226)
573 917.077	8(2, 6)–9(0, 9)	(18.419)	683 597.023	5(4, 2)–6(2, 5)	(0.796)
582 366.393	2(1, 2)–1(0, 1)	(0.188)	683 761.621	5(3, 2)–5(2, 3)	(0.602)
586 448.098	2(2, 1)–2(1, 2)	(0.233)	684 675.824	8(3, 5)–8(2, 6)	(0.950)
586 896.320	3(0, 3)–2(1, 2)	(0.178)	684 945.221	8(5, 4)–9(2, 7)	(10.435)
591 009.270	5(3, 3)–6(1, 6)	(1.393)	687 480.432	4(1, 3)–3(2, 2)	(0.251)
597 526.072	5(3, 3)–6(0, 6)	(1.362)	691 050.292	2(2, 1)–2(0, 2)	(0.298)
598 805.121	6(2, 4)–6(1, 5)	(0.247)	691 498.513	3(0, 3)–2(0, 2)	(0.176)

Note Added in Proof

The line strengths for the H_2S and HDS tables were calculated using wave-functions which included the effects of centrifugal distortion. Changes in the dipole moment due to centrifugal distortion were not included. The authors would like to acknowledge the contribution of Dr. R. L. Cook who developed many of the computer programs used in this work and Prof. W. Gordy for his support and encouragement.

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