Microwave Spectra of Molecules of Astrophysical Interest
I. Formaldehyde, Formamide, and Thioformaldehyde

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The available data on the microwave spectra of formaldehyde, formamide, and thioformaldehyde are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion parameters, dipole moments, hyperfine coupling constants, and structural parameters are tabulated. Observed rotational transitions are presented for the astronomically interesting isotopic forms of these molecules when available. Detailed centrifugal distortion calculations have been carried out for the most abundant isotopic forms of these molecules, namely, $H_2{}^{12}C^{16}O$, $H_2{}^{13}C^{16}O$, $^{14}NH_2{}^{12}CH^{16}O$, and $H_2{}^{12}C^{32}S$. Transitions have been predicted and tabulated for the frequency ranges

1 MHz to 300 GHz for $H_2{}^{12}C^{16}O$,
100 MHz to 300 GHz for $H_2{}^{13}C^{16}O$,
500 MHz to 180 GHz for $^{14}NH_2{}^{12}CH^{16}O$,
and 100 MHz to 300 GHz for $H_2{}^{12}C^{32}S$.

All predicted transitions include 95 percent confidence limits; measured transition error limits have been reproduced from the original literature. References are given for all data included.

Key words: Formaldehyde; formamide; interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; thioformaldehyde.

Contents

1. Introduction

This paper represents the first in a proposed series of critical reviews of the microwave spectra of molecules of astrophysical interest. It has been prepared in response to the rapidly growing needs in the field of molecular radio astronomy for reliable laboratory spectra of selected molecules. The best available data have been gathered for each molecule and subjected to an extensive statistical analysis. This analysis provides the molecular constants for the molecules, a check on the reliability of the measured transitions, and allows the unobserved transitions to be predicted with uncertainty limits in many cases of comparable magnitude to the measurement error. Thus, the spectral information presented in the following tables includes predicted as well as observed transitions in the frequency region presently accessible to the radio telescopes. Although the reported transitions have been limited somewhat by fixing a maximum value for the total rotational energy of the lower state of each transition (this maximum value varies depending on the molecule under consideration), it is felt that these limitations are generous enough to allow for presentation of all lines which might be observed by existing telescopes. In particular it should be possible to identify astronomical observations which may correspond to lines from these molecules in relatively high energy levels. Those transitions which fall outside these energy limitations but which have been observed in the laboratory and have been used in the statistical analysis are also presented in the spectral tables for completeness.

It should be mentioned that, under certain circumstances, the predicted transition frequency may be more reliable than the frequency reported in a laboratory observation. For example, errors in laboratory observations stemming from incomplete resolution of overlapping transitions are not always recognized and occasionally carry over into the published literature. The inaccuracies in these measurements are detected by comparison of the difference between the observed and calculated frequencies with the standard deviation of this difference. However, this is not to say that a careful laboratory measurement under higher resolution would not be better, but only that with the available data the calculated frequency may be more reliable. For the less abundant isotopic species of the molecules reported there are usually insufficient data to present a detailed statistical analysis of the spectrum. In these instances, only the observed transitions are reported. Deuterated species have been intentionally neglected because of the expected low cosmic abundance of the deuterium atom.

In order to reduce transcription errors, the tables of spectra have been reproduced directly from computer printout wherever possible. The open literature has been searched to January, 1972 for information relating to the microwave spectra of all species. All reports published prior to 1960 which were included in Volume IV of NBS Monograph 70 [1][1] will not be directly referenced in the present review. Data taken from these reports are referenced as MON 70. The references listed as preprints were in preprint form at the time of this writing.

The rotational constants, centrifugal distortion constants, and where appropriate, quadrupole coupling constants were obtained from a least squares analysis of the observed spectral data using techniques published elsewhere [2]. Measurements were excluded from the final calculation when they differed from the calculated frequencies by more than 3.5 times the standard deviation of this difference. The probability that the difference between the calculated and observed frequency will exceed 3.5 standard deviations is on the order of one in one thousand.

Because the data used in the analysis of each of the three molecular species reported in this paper were obtained from a variety of sources, the assumption of equally probable errors for each of the transitions included in the fit could not be made. In the analysis, therefore, each transition was weighted by the inverse square of its expected uncertainty. When available, the reported estimates of the measurement uncertainties were used. In some instances these were not available. In these instances, the uncertainties were estimated from the goodness-of-fit using a uniform weighting scheme. It should be noted that the criterion of goodness-of-fit was applied to a particular transition both when it was included in and excluded from the fit. Whenever possible, a uniform uncertainty was assigned to all such transitions taken from a single source. Finally, in certain isolated situations, the reported measurement uncertainty was judged to be underestimated by the criterion of its goodness-of-fit and it was necessary to assign a higher uncertainty to such transitions.

The tables of spectra and molecular parameters are organized by molecule in sections 2, 3, and 4. The details of the tables will be described separately because the reporting format varies with each molecule. For all species, the line strengths have been calculated for all the calculated transitions. The line strengths, denoted by ${}^{x}S(J'_{K'_p,K'_o}; J''_{K''_p,K''_o})$, are defined for all molecules treated in this review as:

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

where the superscript x refers to one of the principal axes of the molecule ($x-a$, b, or c); $|\mu_{J'-J''}|$ 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. The line strength may be related to the Einstein

[1] Numbers in brackets indicate references in section 1.2.

coefficient, A, in the following manner. The probability, $A(J'_{K'_p,K'_o}; J''_{K''_p,K''_o})$, of a spontaneous transition in one second from the higher state, $J'_{K'_p,K'_o}$, to the lower state, $J''_{K''_p,K''_o}$, is

$$A(J'_{K'_p,K'_o}; J''_{K''_p,K''_o}) = \frac{1.1639\times10^{-20}\nu^3\mu_x^2}{2J'+1} {}_xS(J'_{K'_p,K'_o}; J''_{K''_p,K''_o}),$$

where ν is the transition frequency in MHz and μ_x the electric dipole component as defined above in Debye units.

1.1. List of Symbols and Conversion Factors

a. Symbols

A, B, C	Rotational constants (MHz). $A \geqslant B \geqslant C$. ($A = h/8\pi^2 I_a$, etc.)
τ	Quartic centrifugal distortion constant (MHz).
H_K, h_K, h_{JK}	Sextic centrifugal distortion constants (MHz).
Δ	Inertial defect (amu Å²). $\Delta = I_c - I_a - I_b$.
a, b, c	Principal axes corresponding to A, B, and C, respectively.
$\mu_{a,b,c}$	Components of the dipole moment along the principal axes (Debye).
D	Abbreviation for Debye units ($1D = 10^{-18}$ electrostatic units of charge × centimeters, or $1D = 3.33564\times10^{-30}$ coulomb-meter).
$eQq_{aa},\ldots$ / $\chi_{aa},\ldots$	Nuclear electric quadrupole coupling constant along indicated principal axis (MHz).
C_X	Spin-rotation constant related to nucleus X.
$g_X g_Y \mu_n^2 \langle r_{XY}^{-3} \rangle$	Spin-spin constant arising from the interaction of nucleii X and Y.
$r(X-Y)$	Distance between centers of mass of atoms X and Y (Å).
∠XYZ	Angle formed by atoms, X, Y, and Z (degrees).
$I_{a,b,c}$	Moments of intertia of whole molecule with respect to the indicated principal axis.
F	Total angular momentum quantum number which includes the nuclear spin for the nucleus with largest χ or eQq.
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.
(. . .)	Parentheses in the numerical listings contain measured or estimated uncertainties. These should be interpreted as: 1.409 (0.083) ≡ 1.409(83) ≡ 1.409 ± 0.083 MHz.

b. Conversion Factors

The following conversion factors have been used:

$$A, B, C(\text{MHz}) = \frac{5.05376\times10^5}{I_{a,b,c}(\text{amu Å}^2)}$$

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

$$h = 6.626196\times10^{-27}\ \text{erg s}$$

1.2. References

[1] National Bureau of Standards (U.S.), Monograph 70, Vol. IV (1968
[2] William H. Kirchhoff, J. Mol. Spectry. **41**, 333 (1972).

2. Formaldehyde

The rotational constants and centrifugal distortioı constants for $H_2{}^{12}C^{16}O$ and $H_2{}^{13}C^{16}O$ given in table were obtained from a least squares analysis of the ob served spectral lines with a computer program whicl includes centrifugal distortion terms in addition to th basic rigid asymmetric rotor energy matrix. The spec tral information reported includes predicted and ob served transitions between 1 MHz and 300 GHz which is well beyond the region presently accessibl to the radio telescopes. The predicted transitions ar further limited by fixing a maximum value of 100 cm⁻¹ for the total rotational energy of the lower stat of the transition. Observed transitions which fall outsid of the stated limits, but which were actually used in th calculation procedure are included for completeness

The data for the ^{13}C species of formaldehyde are les extensive than those for the ^{12}C species. A least square fit to these data, using the same model as the ^{12}C species gave poorly defined values for τ_{aaaa}, A, the two P constants, and several of the predicted transitions. Sinc it is safe to assume that τ_{aaaa} will not change signif cantly on isotopic substitution at the carbon nucleus the ^{12}C value of τ_{aaaa} was included as a data point i the fit, weighted by the inverse square of its uncertaint For this uncertainty, three times the standard deviatio of the ^{12}C value was used. This estimated uncertaint is larger than the isotope shifts for the other rotationa constants. The rotational constants for $H_2{}^{12}C^{18}O$ i table 1 were taken directly from the literature cited, a were the structural parameters and electric dipol moment.

2.1. Organization of the Spectral Tables

Transitions for which spin-rotation and spin-spi hyperfine splittings have been resolved have bee tabulated in tables 2–5. Table 6 contains observe microwave transitions for $H_2{}^{12}C^{18}O$. These data ar too limited to allow a statistical analysis and have bee transcribed directly from the literature.

Tables 7 and 9 contain the results of a statistica analysis of the reported microwave data on $H_2{}^{12}C^{16}O$ and $H_2{}^{13}C^{16}O$, respectively. For each spectral line th st column of these tables contains the upper state and ver state quantum numbers in the form, $J(K_p, K_o)$ a rigid asymmetric rotor. The quantum numbers followed by the observed line frequency and, in rentheses, the experimentally estimated uncertainty MHz, when available. A single asterisk within the rentheses indicates that the quoted uncertainty is sed on the quality of the least squares fit when the perimental uncertainty is either unknown or judged be underestimated. The uncertainties appearing jacent to the observed line frequencies in tables 7 d 9 were used for calculating the weights for the least uares analysis. References to the laboratory measurements are shown in the last column of the table. Oppo-e the $J(K_p, K_o)$ quantum numbers, the third column ntains the calculated frequency and estimated un-rtainty in MHz. The calculated uncertainties represent percent confidence levels, which are approximately ice (this varies slightly with the number of data in-ıded in the calculation) the standard deviation ob-ned from the least squares analysis.

The line strengths for the rotational transitions are own in brackets in column 4 of tables 7 and 9. The tal rotational energy for the upper and lower rotational vels is given in columns 5 and 6 in units of cm^{-1} rounded to three figures after the decimal. These energies were calculated using all five quartic distortion constants and two sextic constants, viz., h_K and h_{JK}.

As a convenience to the user, the calculated transition frequencies from tables 7 and 9 have been listed according to increasing frequency in tables 8 and 10, respectively. Several transitions which occur between rotational levels whose energy is above the arbitrary cutoff energy of 1000 cm^{-1} have been measured in the laboratory. Since these have been included in the analysis, they are listed in the tables.

2.2. Acknowledgments

The authors are indebted to Dr. John W. C. Johns of the National Research Council of Canada for making his preliminary calculations on formaldehyde available and for generously sharing his extensive collection of laboratory data and references. We are also pleased to acknowledge Mr. Richard Nerf of the Institute for Space Studies, New York, for contributing a valuable set of unpublished laboratory measurements. Dr. Lewis E. Snyder of the University of Virginia is due a special thanks for reviewing and adding to our list of references on formaldehyde.

2.3. Formaldehyde Spectral Tables

TABLE 1. Molecular constants for formaldehyde

	Present results [a]		Previous results		
	$H_2{}^{12}C^{16}O$	$H_2{}^{13}C^{16}O$	$H_2{}^{12}C^{16}O$ [Ref.]	$H_2{}^{13}C^{16}O$ [Ref.]	$H_2{}^{12}C^{18}O$ [Ref.]
Rotational constants					
A(MHz)	281970.37 ± 0.94	281991.50 ± 2.50	282029(25) [60E]	282033(25) [60E]	282029(35) [60E]
B(MHz)	38835.42558 ± 0.00805	37810.50151 ± 0.00532	38835.28(10) [60E]	37810.39(6) [63E]	36904.1(3) [63E]
C(MHz)	34005.73031 ± 0.00817	33217.37768 ± 0.00563	34003.16(10) [60E]	33214.92(6) [63E]	32513.0(3) [63E]
$\Delta = I_c - I_a - I_b$ (Amu Å^2)	+ 0.055920 ± 0.000006	+ 0.056016 ± 0.000016	0.0574(2) [61B]	—	—
Distortion constants					
τ_{aaaa}(MHz)	− 85.391 ± 1.607	− 86.227 ± 4.262	—	—	—
τ_{bbbb}(kHz)	− 385.3273 ± 1.8314	− 363.489 ± 0.934	− 392.20 [61B]	− 372.83 [61B]	—
τ_{cccc}(kHz)	− 218.482 ± 1825	− 209.34 ± 0.91	—	—	—
τ_1(kHz)	− 6079.664 ± 9.109	− 5892.076 ± 9.374	—	—	—
τ_2(kHz)	− 776.0840 ± 1.7940	− 740.4786 ± 1.2084	—	—	—
τ_3(MHz) [b]	+ 28.36 ± 0.10	+ 28.0 ± 0.1	—	—	—
h_K(kHz)	+ 1.603 ± 0.164	+ 0.7812 ± 0.6806	—	—	—
h_{JK}(kHz)	− (0.061 ± 2.972) × 10^{-3}	+ (17.67 ± 11.00) × 10^{-3}	—	—	—

Dipole moment ($H_2^{12}C^{16}O$)

μ_a(Debye) 2.331(30) [60C]

Structure

r_Z(C=O) 1.2078(30) [63E]
r_Z(C−H) 1.1161(70) [63E]
$\angle_Z$HCH 116°31′(40′) [63E]

[a] The number of significant figures quoted are necessary to reproduce all the calculated frequencies within their standard deviations.
[b] The value of τ_3 is set using the planarity conditions and is not, strictly speaking, a determinable parameter.

TABLE 2. Observed hyperfine splittings and constants for the $1_{10}\rightarrow 1_{11}$ transition of $H_2^{12}C^{16}O$

F_U	F_L	Rel. I.	$[\nu-\nu_0]$ (kHz) ref. [71B] $\nu_0=4\ 829\ 659.96(5)$ kHz	$[\nu-\nu_0]$ (kHz) ref. [71D] $\nu_0=4\ 829\ 659.89(12)$ kHz
1	0	4	−18.53(6)	−18.604(76)
0	1	4	−1.34(12) [a]	−1.566(88)
2	2	15	−0.35(5)	−0.344(80)
2	1	5	4.05(5)	4.021(73)
1	2	5	6.48(5)	6.521(57)
1	1	3	11.08(5)	11.146(79)

Spin-Rotation (kHz)

$C_H(1_{10})=-0.82(4)$	$C_H(1_{10})=-0.80(5)$
$C_H(1_{11})=-3.05(4)$	$C_H(1_{10})=-3.07(5)$

Spin-Spin (kHz)

$g_H^2\mu_n^2\langle r_{HH}^{-3}\rangle=17.68(10)$	$g_H^2\mu_n^2\langle r_{HH}^{-3}\rangle=17.74(12)$

[a] Unresolved, calculated from the hyperfine constants.

ABLE 3. Observed hyperfine splittings and constants for the $2_{11}\rightarrow 2_{12}$ and $3_{12}\rightarrow 3_{13}$ transitions of $H_2^{12}C^{16}O$

	F_U	F_L	Rel. I.	$[\nu-\nu_0]$ (kHz)
$_1\rightarrow 2_{12}$ Transition:	2	2	~18	10.12(20)
= 14488.65 MHz	3	3	~42	0.00(30)
ef. [64C]	1	2	~5	−8.5(10)
	1	1	~15	−20.73(30)

Spin-Rotation

$C_H(2_{11})-C_H(2_{12})=2.26(13)$ kHz

$C_H(2_{11})-0.65(50)$ kHz

	F_U	F_L	Rel. I.	$[\nu-\nu_0]$ (kHz)
$_{12}\rightarrow 3_{13}$ Transition:	3	3	~7	10.4(7)
$'_0$ = 28974.85 MHz	4	4	~9	0.0
₹ef. [59A]	2	2	~5	−23.0(15)

Spin-Spin

$g_H^2\mu_n^2\langle r_{HH}^{-3}\rangle=19.9(13)$ kHz

TABLE 4. Observed hyperfine splittings and constants for the $1_{10}\rightarrow 1_{11}$ transition of $H_2^{13}C^{16}O$. (Ref. [71B])

$[F_1, F]_U$	$[F_1, F]_L$	Rel. I.	$[\nu-\nu_0]$ (kHz) $\nu_0=4\ 593\ 088.54(6)$ kHz
1/2, 1/2	3/2, 1/2	1.05	−132.22(14)
1/2, 1/2	3/2, 3/2	1.06	−114.78(14)
1/2, 3/2	3/2, 1/2	0.04	−112.65(25)
1/2, 3/2	3/2, 5/2	2.98	−102.87(9)
1/2, 3/2	3/2, 3/2	1.62	−95.19(14)
1/2, 1/2	1/2, 1/2	0.37	−39.16(16)
1/2, 3/2	1/2, 1/2	3.83	−19.57(7)
1/2, 1/2	1/2, 3/2	4.18	−8.59(25) [a]
3/2, 1/2	3/2, 1/2	2.74	−7.39(10)
3/2, 3/2	3/2, 1/2	2.84	−2.16(25) [a]
3/2, 5/2	3/2, 5/2	14.00	−2.00(5)
3/2, 5/2	3/2, 3/2	2.31	+5.70(15)
3/2, 3/2	3/2, 5/2	3.02	+7.58(15)
3/2, 1/2	3/2, 3/2	2.44	+9.97(15)
1/2, 3/2	1/2, 3/2	4.86	+10.89(25) [a]
3/2, 3/2	3/2, 3/2	5.90	+15.37(11)
3/2, 1/2	1/2, 1/2	1.40	+85.54(10)
3/2, 3/2	1/2, 1/2	1.07	+90.93(10)
3/2, 5/2	1/2, 3/2	3.69	+111.78(8)
3/2, 1/2	1/2, 3/2	0.09	+116.04(25)
3/2, 3/2	1/2, 3/2	0.51	+121.38(20)

Spin-Rotation

$C_C(1_{10})=73.87(14)$ kHz

$C_C(1_{11})=67.79(14)$ kHz

$C_H(1_{10})=-0.77(6)$ kHz

$C_H(1_{11})=-3.03(6)$ kHz

Spin-Spin

$g_H^2\mu_n^2\langle r_{HH}^{-3}\rangle=17.52(17)$ kHz

$g_H g_C\mu_n^2\langle r_{HC}^{-3}\rangle=21.65(18)$ kHz

Calculated.

TABLE 5. Observed hyperfine splittings and constants for the $1_{10} \rightarrow 1_{11}$ transition of $H_2\,{}^{12}C^{18}O$. (Ref. [71B])

F_U	F_L	Rel. I.	$[\nu-\nu_0]$ (kHz) $\nu_0 = 4\,388\,796.98(12)$ kHz
1	0	4	− 18.43(14)
0	1	4	−1.02(30) [a]
2	2	15	− 0.68(8)
2	1	5	+ 4.09(10)
1	2	5	+ 6.56(17)
1	1	3	+ 11.45(13)

Spin-Rotation

$C_H(1_{10}) = -0.98(10)$ kHz
$C_H(1_{11}) = -2.98(10)$ kHz

Spin-Spin

$g_H^2 \mu_n^2 \langle r_{HH}^{-3} \rangle = 17.90(25)$ kHz

[a] Calculated.

TABLE 6. Observed microwave transitions in $H_2\,{}^{12}C^{18}O$ (MHz)

Transition Upper State	Lower State	Observed frequency (est. uncertainty)	Reference
1_{01}	0_{00}	69416.8(4)	[63E]
1_{10}	1_{11}	4388.79698(12)	[71B]
2_{11}	2_{12}	13165.84 [a]	[60D]
3_{12}	3_{13}	26330.64 [a]	[60D]

[a] Experimental uncertainties unavailable.

TABLE 7. The microwave spectrum of $H_2\,{}^{12}C^{16}O$

Transition		Observed frequency (estimated uncertainty)	Calculated frequency (estimated uncertainty)	Line strength	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
1(1, 0) −	1(1, 1)	4829.660(.0001)	4829.660 (.000)	[1.500]	10.700	10.539	71B
1(0, 1) −	0(0, 0)	72837.974(.024)	72837.965 (.025)	[1.000]	2.430	.000	71C
2(1, 1) −	2(1, 2)	14488.650(.1 *)	14488.479 (.001)	[.833]	15.720	15.237	MON70
2(2, 0) −	2(2, 1)		71.139 (.000)	[3.333]	40.042	40.040	
2(0, 2) −	1(0, 1)	145602.971(.03)	145602.980 (.036)	[2.000]	7.286	2.430	71C
2(1, 2) −	1(1, 1)	140839.529(.03)	140839.535 (.033)	[1.500]	15.237	10.539	71C
2(1, 1) −	1(1, 0)	150498.359(.03)	150498.355 (.033)	[1.500]	15.720	10.700	71C
3(1, 2) −	3(1, 3)	28974.800(.01)	28974.804 (.002)	[.583]	23.249	22.282	71E
3(2, 1) −	3(2, 2)	355.586(.2 *)	355.568 (.000)	[2.332]	47.339	47.327	63A
3(0, 3) −	2(0, 2)	218222.186(.049)	218222.221 (.059)	[2.999]	14.566	7.286	71C
3(1, 3) −	2(1, 2)	211211.469(.05)	211211.466 (.046)	[2.667]	22.282	15.237	71C
3(1, 2) −	2(1, 1)	225697.787(.08)	225697.791 (.046)	[2.667]	23.249	15.720	71C
3(2, 2) −	2(2, 1)	218475.619(.06)	218475.606 (.083)	[1.667]	47.327	40.040	71C
3(2, 1) −	2(2, 0)	218760.080(.06)	218760.034 (.083)	[1.667]	47.339	40.042	71C
4(1, 3) −	4(1, 4)	48284.521(.01)	48284.519 (.007)	[.450]	33.283	31.673	71C
4(2, 2) −	4(2, 3)	1065.850(.2 *)	1065.869 (.001)	[1.798]	57.078	57.042	63A
4(3, 1) −	4(3, 2)	4.573(.0002)	4.573 (.000)	[4.049]	97.956	97.956	66B
4(0, 4) −	3(0, 3)		290623.440 (.160)	[3.999]	24.260	14.566	
4(1, 4) −	3(1, 3)	281526.949(.12)	281526.921 (.146)	[3.750]	31.673	22.282	71C
4(1, 3) −	3(1, 2)	300836.609(.13)	300836.637 (.146)	[3.750]	33.283	23.249	71C
4(2, 3) −	3(2, 2)		291237.699 (.153)	[3.000]	57.042	47.327	
4(2, 2) −	3(2, 1)		291948.000 (.153)	[3.000]	57.078	47.339	
4(3, 2) −	3(3, 1)		291380.275 (.284)	[1.750]	97.956	88.237	
4(3, 1) −	3(3, 0)		291384.194 (.284)	[1.750]	97.956	88.237	
5(1, 4) −	5(1, 5)	72409.099(.03)	72409.097 (.015)	[.367]	45.822	43.407	71C
5(2, 3) −	5(2, 4)		2483.408 (.003)	[1.463]	69.265	69.182	
5(3, 2) −	5(3, 3)	18.284(.0004)	18.283 (.000)	[3.299]	110.107	110.107	66B
6(1, 5) −	6(1, 6)	101332.991(.044)	101333.003 (.031)	[.310]	60.860	57.480	71C
6(2, 4) −	6(2, 5)	4954.760(.1 *)	4954.712 (.005)	[1.232]	83.910	83.745	MON70
6(3, 3) −	6(3, 4)	54.837(.02 *)	54.818 (.000)	[2.784]	124.692	124.690	68A
7(1, 6) −	7(1, 7)	135030.467(.03)	135030.483 (.056)	[.269]	78.395	73.891	71C
7(2, 5) −	7(2, 6)	8884.870(.1 *)	8884.822 (.009)	[1.063]	101.025	100.728	MON70
7(3, 4) −	7(3, 5)		136.927 (.001)	[2.408]	141.712	141.707	
8(1, 7) −	8(1, 8)		173461.764 (.093)	[.238]	98.420	92.634	
8(2, 6) −	8(2, 7)	14726.740(.1 *)	14726.639 (.013)	[.932]	120.620	120.129	MON70
8(3, 5) −	8(3, 6)	301.100(.2 *)	300.872 (.001)	[2.121]	161.169	161.159	63A
8(4, 4) −	8(4, 5)	2.454(.002*)	2.452 (.000)	[3.776]	218.328	218.328	68A
9(1, 8) −	9(1, 9)		216568.743 (.146)	[.213]	120.929	113.705	
9(2, 7) −	9(2, 8)	22965.710(.1 *)	22965.625 (.017)	[.827]	142.709	141.943	MON70
9(3, 6) −	9(3, 7)	601.074(.2 *)	600.745 (.003)	[1.894]	183.066	183.046	63A
9(4, 5) −	9(4, 6)	6.374(.002*)	6.369 (.000)	[3.375]	240.198	240.198	68A
10(1, 9) −	10(1,10)		264270.233 (.220)	[.194]	145.915	137.100	
10(2, 8) −	10(2, 9)	34100.050(.01)	34100.045 (.022)	[.741]	167.304	166.166	71E
10(3, 7) −	10(3, 8)		1113.197 (.004)	[1.710]	207.407	207.370	
10(4, 6) −	10(4, 7)	14.845(.001*)	14.847 (.000)	[3.051]	264.501	264.500	68A
11(2, 9) −	11(2,10)	48612.700(5.0 *)	48617.983 (.032)	[.669]	194.417	192.795	MON70
11(3, 8)	11(3, 9)		1942.463 (.007)	[1.558]	234.196	234.131	
11(4, 7) −	11(4, 8)	31.773(.001)	31.774 (.001)	[2.783]	291.238	291.237	68A
12(2,10) −	12(2,11)		66973.497 (.059)	[.607]	224.058	221.824	

TABLE 7. The microwave spectrum of $H_2{}^{12}C^{16}O$ – Continued

Transition: Upper state	Transition: Lower state	Observed frequency (estimated uncertainty)	Calculated frequency (estimated uncertainty)	Line strength	Energy levels in cm⁻¹: Upper state	Energy levels in cm⁻¹: Lower state	Reference
12(3, 9)	– 12(3,10)	3225.580(.1 *)	3225.439 (.010)	[1.429]	263.438	263.330	MON70
12(4, 8)	– 12(4, 9)		63.448 (.001)	[2.557]	320.411	320.409	
13(2,11)	– 13(2,12)		89564.976 (.113)	[.553]	256.236	253.249	
13(3,10)	– 13(3,11)	5136.580(.1 *)	5136.558 (.014)	[1.318]	295.138	294.967	MON70
13(4, 9)	– 13(4,10)		119.618 (.002)	[2.365]	352.021	352.017	
13(5, 8)	– 13(5, 9)		1.475 (.000)	[3.704]	425.333	425.333	
14(2,12)	– 14(2,13)		116718.616 (.207)	[.505]	290.956	287.062	
14(3,11)	– 14(3,12)	7892.030(.1 *)	7892.057 (.018)	[1.222]	329.305	329.041	MON70
14(4,10)	– 14(4,11)		214.818 (.003)	[2.199]	386.070	386.062	
14(5, 9)	– 14(5,10)		3.110 (.000)	[3.446]	459.341	459.341	
15(2,13)	– 15(2,14)		148678.939 (.351)	[.464]	328.219	323.259	
15(3,12)	– 15(3,13)	11753.130(.1 *)	11753.148 (.021)	[1.136]	365.945	365.553	MON70
15(4,11)	– 15(4,12)		370.027 (.005)	[2.054]	422.558	422.546	
15(5,10)	– 15(5,11)	6.212(.001*)	6.211 (.000)	[3.221]	495.782	495.782	68A
16(2,14)	– 16(2,15)		185606.676 (.561)	[.427]	368.025	361.834	
16(3,13)	– 16(3,14)	17027.600(.1 *)	17027.506 (.023)	[1.060]	405.068	404.500	MON70
16(4,12)	– 16(4,13)		614.697 (.008)	[1.926]	461.490	461.469	
16(5,11)	– 16(5,12)	11.836(.001*)	11.834 (.001)	[3.024]	534.656	534.655	68A
17(2,15)	– 17(2,16)		227582.786 (.851)	[.395]	410.370	402.779	
17(3,14)	– 17(3,15)	24068.310(.1 *)	24068.374 (.022)	[.991]	446.683	445.880	MON70
17(4,13)	– 17(4,14)		989.151 (.012)	[1.811]	502.865	502.832	
17(5,12)	– 17(5,13)	21.647(.001*)	21.648 (.001)	[2.848]	575.963	575.962	68A
18(2,16)	– 18(2,17)		274616.407 (1.235)	[.366]	455.248	446.088	
18(3,15)	– 18(3,16)	33270.590(.01)	33270.600 (.021)	[.928]	490.802	489.693	71E
18(4,14)	– 18(4,15)		1547.377 (.016)	[1.709]	546.689	546.637	
18(5,13)	– 18(5,14)		38.204 (.002)	[2.691]	619.704	619.703	
19(3,16)	– 19(3,17)	45063.100(.1)	45063.018 (.036)	[.870]	537.436	535.933	MON70
19(4,15)	– 19(4,16)		2360.203 (.022)	[1.616]	592.963	592.884	
19(5,14)	– 19(5,15)		65.305 (.004)	[2.550]	665.880	665.878	
19(6,13)	– 19(6,14)		1.110 (.000)	[3.684]	755.155	755.155	
20(3,17)	– 20(3,18)		59896.877 (.083)	[.816]	586.596	584.598	
20(4,16)	– 20(4,17)	3518.850(.5)	3518.810 (.028)	[1.532]	641.691	641.574	MON70
20(5,15)	– 20(5,16)		108.489 (.005)	[2.422]	714.493	714.489	
20(6,14)	– 20(6,15)		2.056 (.000)	[3.502]	803.705	803.705	
21(3,18)	– 21(3,19)		78230.496 (.168)	[.766]	638.293	635.683	
21(4,17)	– 21(4,18)	5138.570(.5)	5138.505 (.034)	[1.454]	692.878	692.706	MON70
21(5,16)	– 21(5,17)		175.648 (.008)	[2.306]	765.542	765.536	
21(6,15)	– 21(6,16)		3.692 (.001)	[3.337]	854.685	854.685	
22(3,19)	– 22(3,20)	100511.100(.15 *)	100511.002 (.309)	[.719]	692.536	689.184	71A
22(4,18)	– 22(4,19)	7362.600(.1 *)	7362.643 (.041)	[1.382]	746.528	746.282	MON70
22(5,17)	– 22(5,18)		277.819 (.012)	[2.199]	819.029	819.020	
22(6,16)	– 22(6,17)		6.442 (.001)	[3.185]	908.093	908.093	
23(3,20)	– 23(3,21)		127154.668 (.529)	[.674]	749.336	745.095	
23(4,19)	– 23(4,20)	10366.510(.1 *)	10366.508 (.046)	[1.316]	802.647	802.301	MON70
23(5,18)	– 23(5,19)		430.162 (.016)	[2.101]	874.956	874.942	
23(6,17)	– 23(6,18)		10.956 (.002)	[3.047]	963.931	963.931	
24(3,21)	– 24(3,22)		158527.929 (.856)	[.633]	808.697	803.409	
24(4,20)	– 24(4,21)	14361.540(.5 *)	14360.902 (.049)	[1.253]	861.242	860.763	MON70
24(5,19)	– 24(5,20)		653.162 (.022)	[2.010]	933.324	933.302	
25(3,22)	– 25(3,23)		194931.260 (1.325)	[.594]	870.624	864.121	
25(4,21)	– 25(4,22)	19595.230(.1 *)	19595.099 (.048)	[1.195]	922.319	921.665	MON70
25(5,20)	– 25(5,21)		974.081 (.030)	[1.926]	994.133	994.101	
26(3,23)	– 26(3,24)		236587.747 (1.974)	[.558]	935.116	927.224	
26(4,22)	– 26(4,23)	26358.820(.1 *)	26358.760 (.042)	[1.139]	985.886	985.007	MON70
27(3,24)	– 27(3,25)		283637.310 (2.846)	[.524]	1002.171	992.710	
27(4,23)	– 27(4,24)	34982.290(.02 *)	34982.288 (.043)	[1.087]	1051.954	1050.787	71E
28(4,24)	– 28(4,25)	45835.580(.2 *)	45835.073 (.083)	[1.036]	1120.530	1119.002	MON70
31(5,26)	– 31(5,27)	7833.200(.1 *)	7833.174 (.094)	[1.519]	1410.399	1410.138	MON70
32(5,27)	– 32(5,28)	10608.740(.2 *)	10608.546 (.110)	[1.463]	1488.372	1488.018	60D
33(5,28)	– 33(5,29)	14211.680(.2 *)	14211.694 (.136)	[1.409]	1568.813	1568.338	60D
34(5,29)	– 34(5,30)	18841.200(.2 *)	18841.412 (.183)	[1.357]	1651.725	1651.096	60D
35(5,30)	– 35(5,31)	24730.400(.2 *)	24730.722 (.264)	[1.307]	1737.116	1736.291	60D

*Experimental uncertainties unavailable. The numbers enclosed in parenthesis are estimated uncertainties used in the weighted fit.

TABLE 8. Calculated microwave transitions in $H_2{}^{12}C^{16}O$ (MHz)

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
1.110	19(6,13) – 19(6,14)	(.000)	18.283	5(3, 2) – 5(3, 3)	(.000)
1.475	13(5, 8) – 13(5, 9)	(.000)	21.648	17(5,12) – 17(5,13)	(.001)
2.056	20(6,14) – 20(6,15)	(.000)	31.774	11(4, 7) – 11(4, 8)	(.001)
2.452	8(4, 4) – 8(4, 5)	(.000)	38.204	18(5,13) – 18(5,14)	(.002)
3.110	14(5, 9) – 14(5,10)	(.000)	54.818	6(3, 3) – 6(3, 4)	(.000)
3.692	21(6,15) – 21(6,16)	(.001)	63.448	12(4, 8) – 12(4, 9)	(.001)
4.573	4(3, 1) – 4(3, 2)	(.000)	65.305	19(5,14) – 19(5,15)	(.004)
6.211	15(5,10) – 15(5,11)	(.000)	71.139	2(2, 0) – 2(2, 1)	(.000)
6.369	9(4, 5) – 9(4, 6)	(.000)	108.489	20(5,15) – 20(5,16)	(.005)
6.442	22(6,16) – 22(6,17)	(.001)	119.618	13(4, 9) – 13(4,10)	(.002)
10.956	23(6,17) – 23(6,18)	(.002)	136.927	7(3, 4) – 7(3, 5)	(.001)
11.834	16(5,11) – 16(5,12)	(.001)	175.648	21(5,16) – 21(5,17)	(.008)
14.847	10(4, 6) – 10(4, 7)	(.000)	214.818	14(4,10) – 14(4,11)	(.003)

TABLE 8. Calculated microwave transitions in $H_2{}^{12}C^{16}O$ (MHz)—Continued

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
277.819	22(5,17) – 22(5,18)	(.012)	34100.044	10(2, 8) – 10(2, 9)	(.022)
300.872	8(3, 5) – 8(3, 6)	(.001)	34982.288	27(4,23) – 27(4,24)	(.043)
355.568	3(2, 1) – 3(2, 2)	(.000)	45063.018	19(3,16) – 19(3,17)	(.036)
370.027	15(4,11) – 15(4,12)	(.005)	45835.072	28(4,24) – 28(4,25)	(.083)
430.162	23(5,18) – 23(5,19)	(.016)	48284.519	4(1, 3) – 4(1, 4)	(.007)
600.745	9(3, 6) – 9(3, 7)	(.003)	48617.982	11(2, 9) – 11(2,10)	(.032)
614.697	16(4,12) – 16(4,13)	(.008)	59896.876	20(3,17) – 20(3,18)	(.083)
653.162	24(5,19) – 24(5,20)	(.022)	66973.496	12(2,10) – 12(2,11)	(.059)
974.081	25(5,20) – 25(5,21)	(.030)	72409.097	5(1, 4) – 5(1, 5)	(.015)
989.151	17(4,13) – 17(4,14)	(.012)	72837.965	1(0, 1) – 0(0, 0)	(.025)
1065.869	4(2, 2) – 4(2, 3)	(.001)	78230.496	21(3,18) – 21(3,19)	(.168)
1113.197	10(3, 7) – 10(3, 8)	(.004)	89564.976	13(2,11) – 13(2,12)	(.113)
1547.377	18(4,14) – 18(4,15)	(.016)	100511.002	22(3,19) – 22(3,20)	(.309)
1942.463	11(3, 8) – 11(3, 9)	(.007)	101333.003	6(1, 5) – 6(1, 6)	(.031)
2360.203	19(4,15) – 19(4,16)	(.022)	116718.615	14(2,12) – 14(2,13)	(.207)
2483.408	5(2, 3) – 5(2, 4)	(.003)	127154.668	23(3,20) – 23(3,21)	(.529)
3225.439	12(3, 9) – 12(3,10)	(.010)	135030.482	7(1, 6) – 7(1, 7)	(.056)
3518.810	20(4,16) – 20(4,17)	(.028)	140839.533	2(1, 2) – 1(1, 1)	(.033)
4829.660	1(1, 0) – 1(1, 1)	(.000)	145602.979	2(0, 2) – 1(0, 1)	(.036)
4954.712	6(2, 4) – 6(2, 5)	(.005)	148678.937	15(2,13) – 15(2,14)	(.351)
5136.558	13(3,10) – 13(3,11)	(.014)	150498.354	2(1, 1) – 1(1, 0)	(.033)
5138.505	21(4,17) – 21(4,18)	(.034)	158527.928	24(3,21) – 24(3,22)	(.856)
7362.643	22(4,18) – 22(4,19)	(.041)	173461.764	8(1, 7) – 8(1, 8)	(.093)
7833.174	31(5,26) – 31(5,27)	(.094)	185606.676	16(2,14) – 16(2,15)	(.561)
7892.057	14(3,11) – 14(3,12)	(.018)	194931.260	25(3,22) – 25(3,23)	(1.325)
8884.822	7(2, 5) – 7(2, 6)	(.009)	211211.465	3(1, 3) – 2(1, 2)	(.046)
10366.508	23(4,19) – 23(4,20)	(.046)	216568.742	9(1, 8) – 9(1, 9)	(.146)
10608.546	32(5,27) – 32(5,28)	(.110)	218222.221	3(0, 3) – 2(0, 2)	(.050)
11753.148	15(3,12) – 15(3,13)	(.021)	218475.605	3(2, 2) – 2(2, 1)	(.083)
14211.694	33(5,28) – 33(5,29)	(.136)	218760.033	3(2, 1) – 2(2, 0)	(.083)
14360.902	24(4,20) – 24(4,21)	(.049)	225697.789	3(1, 2) – 2(1, 1)	(.046)
14488.479	2(1, 1) – 2(1, 2)	(.001)	227582.785	17(2,15) – 17(2,16)	(.851)
14726.638	8(2, 6) – 8(2, 7)	(.013)	236587.746	26(3,23) – 26(3,24)	(1.974)
17027.506	16(3,13) – 16(3,14)	(.023)	264270.230	10(1, 9) – 10(1,10)	(.220)
18841.411	34(5,29) – 34(5,30)	(.183)	274616.406	18(2,16) – 18(2,17)	(1.235)
19595.099	25(4,21) – 25(4,22)	(.048)	281526.918	4(1, 4) – 3(1, 3)	(.146)
22965.625	9(2, 7) – 9(2, 8)	(.017)	283637.309	27(3,24) – 27(3,25)	(2.846)
24068.374	17(3,14) – 17(3,15)	(.022)	290623.437	4(0, 4) – 3(0, 3)	(.160)
24730.722	35(5,30) – 35(5,31)	(.264)	291237.695	4(2, 3) – 3(2, 2)	(.153)
26358.760	26(4,22) – 26(4,23)	(.042)	291380.273	4(3, 2) – 3(3, 1)	(.284)
28974.804	3(1, 2) – 3(1, 3)	(.002)	291384.191	4(3, 1) – 3(3, 0)	(.284)
33270.599	18(3,15) – 18(3,16)	(.021)	291947.996	4(2, 2) – 3(2, 1)	(.153)
			300836.633	4(1, 3) – 3(1, 2)	(.146)

TABLE 9. The microwave spectrum of $H_2{}^{13}C^{16}O$

Transition		Observed frequency (estimated uncertainty)	Calculated frequency (estimated uncertainty)	Line strength	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
1(1, 0) –	1(1, 1)	4593.089(.0001)	4593.089 (.000)	[1.500]	10.667	10.513	71B
1(0, 1) –	0(0, 0)	71024.797(.020)	71024.790 (.015)	[1.000]	2.369	.000	71C
2(1, 1) –	2(1, 2)	13778.860(.1 *)	13778.804 (.001)	[.833]	15.558	15.098	MON70
2(0, 2) –	1(0, 1)	141983.748(.032)	141983.764 (.024)	[2.000]	7.105	2.369	71C
2(1, 2) –	1(1, 1)	137449.969(.030)	137449.971 (.022)	[1.500]	15.098	10.513	71C
2(1, 1) –	1(1, 0)	146635.689(.033)	146635.686 (.022)	[1.500]	15.558	10.667	71C
3(1, 2) –	3(1, 3)	27555.680(.02)	27555.666 (.003)	[.583]	22.893	21.974	71E
3(2, 1) –	3(2, 2)		320.382 (.002)	[2.333]	47.099	47.088	
3(0, 3) –	2(0, 2)	212811.221(.047)	212811.211 (.037)	[2.999]	14.204	7.105	71C
3(1, 3) –	2(1, 2)	206131.629(.046)	206131.641 (.026)	[2.667]	21.974	15.098	71C
3(1, 2) –	2(1, 1)	219908.525(.056)	219908.502 (.026)	[2.667]	22.893	15.558	71C
3(2, 2) –	2(2, 1)	213037.359(.12)	213037.299 (.099)	[1.667]	47.088	39.982	71C
3(2, 1) –	2(2, 0)	213293.500(.12)	213293.583 (.099)	[1.667]	47.099	39.984	71C
4(1, 3) –	4(1, 4)	45920.064(.010)	45920.059 (.010)	[.450]	32.671	31.139	71C
4(2, 2) –	4(2, 3)		960.465 (.006)	[1.798]	56.593	56.561	
4(0, 4) –	3(0, 3)		283441.888 (.087)	[3.999]	23.658	14.204	
4(1, 4) –	3(1, 3)	274762.121(.19)	274762.124 (.071)	[3.750]	31.139	21.974	71C
4(1, 3) –	3(1, 2)	293126.516(.065)	293126.517 (.071)	[3.750]	32.671	22.893	71C
4(2, 3) –	3(2. 2)		283992.481 (.135)	[3.000]	56.561	47.088	
4(2, 2) –	3(2, 1)		284632.564 (.135)	[3.000]	56.593	47.099	
4(3, 2) –	3(3, 1)		284117.300 (.326)	[1.750]	97.629	88.151	
4(3, 1) –	3(3, 0)		284120.645 (.326)	[1.750]	97.629	88.151	
5(1, 4) –	5(1, 5)	68864.551(.028)	68864.566 (.024)	[.367]	44.888	42.591	71C
5(2, 3) –	5(2, 4)		2238.138 (.013)	[1.464]	68.474	68.399	
6(1, 5) –	6(1, 6)		96375.752 (.048)	[.310]	59.542	56.328	
6(2, 4) –	6(2, 5)		4466.428 (.025)	[1.233]	82.750	82.601	
7(1, 6) –	7(1, 7)	128431.390(.22)	128431.420 (.086)	[.269]	76.629	72.345	71C
7(2, 5) –	7(2, 6)	8012.560(.5)	8012.181 (.043)	[1.064]	99.430	99.163	MON70
7(3, 4) –	7(3, 5)		116.898 (.003)	[2.408]	140.292	140.288	
8(1, 7) –	8(1, 8)		164997.357 (.144)	[.238]	96.144	90.640	
8(2, 6) –	8(2, 7)	13287.130(.5 *)	13287.334 (.068)	[.933]	118.526	118.082	60D
8(3, 5) –	8(3, 6)		256.891 (.007)	[2.121]	159.262	159.254	
9(1, 8) –	9(1, 9)		206023.629 (.226)	[.213]	118.081	111.209	

Transition		Observed frequency	Calculated frequency		Energy levels in cm⁻¹		
Upper state	Lower state	(estimated uncertainty)	(estimated uncertainty)	Line strength	Upper state	Lower state	Reference
9(2, 7)	– 9(2, 8)	20736.400(.5)	20736.261 (.099)	[.829]	140.048	139.357	60D
9(3, 6)	– 9(3, 7)		513.007 (.013)	[1.895]	180.611	180.594	
10(1, 9)	– 10(1,10)		251440.493 (.339)	[.194]	142.435	134.048	
10(2, 8)	– 10(2, 9)	30819.200(.1)	30819.216 (.138)	[.743]	164.010	162.982	71E
10(3, 7)	– 10(3, 8)		950.815 (.021)	[1.711]	204.342	204.310	
11(1,10)	– 11(1,11)		301154.026 (.490)	[.178]	169.197	159.151	
11(2, 9)	– 11(2,10)		43992.672 (.189)	[.671]	190.422	188.954	
11(3, 8)	– 11(3, 9)		1659.577 (.033)	[1.559]	230.457	230.402	
12(2,10)	– 12(2,11)		60688.344 (.269)	[.609]	219.293	217.269	
12(3, 9)	– 12(3,10)		2756.712 (.047)	[1.430]	258.962	258.870	
13(2,11)	– 13(2,12)		81293.325 (.405)	[.556]	250.633	247.921	
13(3,10)	– 13(3,11)		4392.150 (.062)	[1.320]	289.861	289.715	
14(2,12)	– 14(2,13)		106133.906 (.632)	[.509]	284.447	280.906	
14(3,11)	– 14(3,12)	6752.310(.5)	6752.290 (.077)	[1.224]	323.162	322.937	MON70
14(4,10)	– 14(4,11)		173.844 (.019)	[2.200]	380.189	380.183	
15(2,13)	– 15(2,14)		135465.015 (.990)	[.467]	320.737	316.219	
15(3,12)	– 15(3,13)	10063.820(.5 *)	10063.170 (.086)	[1.139]	358.870	358.534	60D
15(4,11)	– 15(4,12)		299.525 (.029)	[2.055]	415.762	415.752	
16(2,14)	– 16(2,15)		169466.022 (1.515)	[.431]	359.505	353.852	
16(3,13)	– 16(3,14)	14592.440(.1)	14592.386 (.084)	[1.063]	396.994	396.507	MON70
16(4,12)	– 16(4,13)		497.729 (.044)	[1.927]	453.716	453.700	
17(2,15)	– 17(2,16)		208242.334 (2.245)	[.398]	400.748	393.802	
17(3,14)	– 17(3,15)	20649.300(.1)	20649.216 (.061)	[.995]	437.542	436.853	MON70
17(4,13)	– 17(4,14)		801.219 (064)	[1.813]	494.052	494.026	
18(2,16)	– 18(2,17)		251831.193 (3.214)	[.370]	444.460	436.060	
18(3,15)	– 18(3,16)	28582.360(.02)	28582.364 (.028)	[.933]	480.524	479.571	71E
18(4,14)	– 18(4,15)		1253.926 (.087)	[1.711]	536.773	536.731	
19(2,17)	– 19(2,18)		300209.638 (4.455)	[.344]	490.635	480.621	
19(3,16)	– 19(3,17)		38774.775 (.125)	[.876]	525.951	524.658	
19(4,15)	– 19(4,16)		1913.578 (.115)	[1.619]	581.880	581.816	
20(3,17)	– 20(3,18)		51635.157 (.319)	[.823]	573.832	572.110	
20(4,16)	– 20(4,17)		2854.645 (.144)	[1.535]	629.378	629.282	
21(3,18)	– 21(3,19)		67586.136 (.631)	[.773]	624.178	621.924	
21(4,17)	– 21(4,18)		4171.543 (.172)	[1.458]	679.269	679.130	
21(5,16)	– 21(5,17)		134.783 (.039)	[2.308]	752.284	752.280	
22(3,19)	– 22(3,20)		87049.462 (1.103)	[.727]	676.999	674.096	
22(4,18)	– 22(4,19)		5982.018 (.191)	[1.387]	731.558	731.358	
22(5,17)	– 22(5,18)		213.264 (.056)	[2.202]	804.429	804.422	
23(3,20)	– 23(3,21)		110429.240 (1.795)	[.683]	732.304	728.620	
23(4,19)	– 23(4,20)		8430.593 (.195)	[1.321]	786.250	785.968	
23(5,18)	– 23(5,19)		330.350 (.079)	[2.104]	858.951	858.940	
24(3,21)	– 24(3,22)		138094.688 (2.778)	[.642]	790.099	785.493	
24(4,20)	– 24(4,21)	11691.800(.2 *)	11691.889 (.179)	[1.259]	843.349	842.959	64B
24(5,19)	– 24(5,20)		501.850 (.109)	[2.014]	915.850	915.834	
25(3,22)	– 25(3,23)		170364.233 (4.137)	[.603]	850.389	844.706	
25(4,21)	– 25(4,22)	15973.370(.2 *)	15973.599 (.160)	[1.201]	902.863	902.330	64B
25(5,20)	– 25(5,21)		748.834 (.144)	[1.930]	975.129	975.104	
26(3,23)	– 26(3,24)		207492.703 (5.967)	[.567]	913.177	906.256	
26(4,22)	– 26(4,23)	21519.000(.2 *)	21518.794 (.239)	[1.147]	964.797	964.080	64B
27(3,24)	– 27(3,25)		249662.917 (8.373)	[.534]	978.462	970.134	

*Experimental uncertainties unavailable. The numbers enclosed in parenthesis are estimated uncertainties used in the weighted fit.

TABLE 10. Calculated microwave transitions in $H_2{}^{13}C^{16}O$ (MHz)

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
116.898	7(3, 4) – 7(3, 5)	(.003)	6752.290	14(3,11) – 14(3,12)	(.077)
134.783	21(5,16) – 21(5,17)	(.039)	8012.181	7(2, 5) – 7(2, 6)	(.043)
173.844	14(4,10) – 14(4,11)	(.019)	8430.592	23(4,19) – 23(4,20)	(.195)
213.264	22(5,17) – 22(5,18)	(.056)	10063.170	15(3,12) – 15(3,13)	(.086)
256.891	8(3, 5) – 8(3, 6)	(.007)	11691.889	24(4,20) – 24(4,21)	(.179)
299.525	15(4,11) – 15(4,12)	(.029)	13287.334	8(2, 6) – 8(2, 7)	(.068)
320.382	3(2, 1) – 3(2, 2)	(.002)	13778.804	2(1, 1) – 2(1, 2)	(.001)
330.350	23(5,18) – 23(5,19)	(.079)	14592.386	16(3,13) – 16(3,14)	(.084)
497.729	16(4,12) – 16(4,13)	(.044)	15973.599	25(4,21) – 25(4,22)	(.160)
501.850	24(5,19) – 24(5,20)	(.109)	20649.216	17(3,14) – 17(3,15)	(.061)
513.007	9(3, 6) – 9(3, 7)	(.013)	20736.261	9(2, 7) – 9(2, 8)	(.099)
748.834	25(5,20) – 25(5,21)	(.144)	21518.794	26(4,22) – 26(4,23)	(.239)
801.219	17(4,13) – 17(4,14)	(.064)	27555.666	3(1, 2) – 3(1, 3)	(.003)
950.815	10(3, 7) – 10(3, 8)	(.021)	28582.364	18(3,15) – 18(3,16)	(.028)
960.465	4(2, 2) – 4(2, 3)	(.006)	30819.216	10(2, 8) – 10(2, 9)	(.138)
1253.926	18(4,14) – 18(4,15)	(.087)	38774.774	19(3,16) – 19(3,17)	(.125)
1659.577	11(3, 8) – 11(3, 9)	(.033)	43992.672	11(2, 9) – 11(2,10)	(.189)
1913.578	19(4,15) – 19(4,16)	(.115)	45920.059	4(1, 3) – 4(1, 4)	(.010)
2238.138	5(2, 3) – 5(2, 4)	(.013)	51635.157	20(3,17) – 20(3,18)	(.319)
2756.712	12(3, 9) – 12(3,10)	(.047)	60688.344	12(2,10) – 12(2,11)	(.269)
2854.645	20(4,16) – 20(4,17)	(.144)	67586.136	21(3,18) – 21(3,19)	(.631)
4171.543	21(4,17) – 21(4,18)	(.172)	68864.565	5(1, 4) – 5(1, 5)	(.024)
4392.150	13(3,10) – 13(3,11)	(.062)	71024.789	1(0, 1) – 0(0, 0)	(.015)
4466.428	6(2, 4) – 6(2, 5)	(.025)	81293.324	13(2,11) – 13(2,12)	(.405)
4593.089	1(1, 0) – 1(1, 1)	(.000)	87049.462	22(3,19) – 22(3,20)	(1.103)
5982.018	22(4,18) – 22(4,19)	(.191)	96375.752	6(1, 5) – 6(1, 6)	(.048)

TABLE 10. Calculated microwave transitions in $H_2{}^{13}C^{16}O$ (MHz)—Continued

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
106133.905	14(2,12) – 14(2,13)	(.632)	213037.299	3(2, 2) – 2(2, 1)	(.099)
110429.239	23(3,20) – 23(3,21)	(1.795)	213293.582	3(2, 1) – 2(2, 0)	(.099)
128431.420	7(1, 6) – 7(1, 7)	(.086)	219908.502	3(1, 2) – 2(1, 1)	(.026)
135465.014	15(2,13) – 15(2,14)	(.990)	249662.916	27(3,24) – 27(3,25)	(8.373)
137449.971	2(1, 2) – 1(1, 1)	(.022)	251440.492	10(1, 9) – 10(1,10)	(.339)
138094.687	24(3,21) – 24(3,22)	(2.778)	251831.191	18(2,16) – 18(2,17)	(3.214)
141983.764	2(0, 2) – 1(0, 1)	(.024)	274762.121	4(1, 4) – 3(1, 3)	(.071)
146635.686	2(1, 1) – 1(1, 0)	(.022)	283441.887	4(0, 4) – 3(0, 3)	(.087)
164997.355	8(1, 7) – 8(1, 8)	(.144)	283992.480	4(2, 3) – 3(2, 2)	(.135)
169466.021	16(2,14) – 16(2,15)	(1.515)	284117.297	4(3, 2) – 3(3, 1)	(.326)
170364.232	25(3,22) – 25(3,23)	(4.137)	284120.645	4(3, 1) – 3(3, 0)	(.326)
206023.629	9(1, 8) – 9(1, 9)	(.226)	284632.562	4(2, 2) – 3(2, 1)	(.135)
206131.639	3(1, 3) – 2(1, 2)	(.026)	293126.516	4(1, 3) – 3(1, 2)	(.071)
207492.701	26(3,23) – 26(3,24)	(5.967)	300209.637	19(2,17) – 19(2,18)	(4.455)
208242.334	17(2,15) – 17(2,16)	(2.245)	301154.023	11(1,10) – 11(1,11)	(.490)
212811.211	3(0, 3) – 2(0, 2)	(.037)			

2.4. H_2CO References

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3. Formamide

The rotational constants, centrifugal distortion constants, and quadrupole coupling constants shown in table 11 for $^{14}NH_2{}^{12}CH^{16}O$ were obtained from a least squares analysis of the observed spectral lines with a computer program which includes nuclear electric quadrupole interaction terms and centrifugal distortion terms in addition to the basic rigid asymmetric rotor energy matrix. The spectral information reported includes predicted as well as observed transitions throughout the frequency range from 500 MHz to 180 GHz. The predicted transitions were further limited by fixing a maximum value for the total rotational energy of 200 cm^{-1} for the lower state of the transition. The rotational constants for $^{15}NH_2{}^{12}CH^{16}O$ shown in table 11 were taken directly from the literature cited, as were the structural parameters and electric dipole moments.

3.1. Organization of the Spectral Tables

Since the data available for $^{15}NH_2{}^{12}CH^{16}O$ were more limited than for $^{14}NH_2{}^{12}CH^{16}O$, a least squares analysis was not feasible. However, a list of the observed transition frequencies has been included in table 12. Table 13 contains the results of the statistical analysis of the spectrum of $^{14}NH_2{}^{12}CH^{16}O$. For each spectral line the first column of table 13 contains the upper state and lower state quantum numbers in the form, $J(K_p, K_o)$ for a rigid asymmetric rotor plus the total angular momentum quantum number $F=J+I_1, J+I_1-1, \ldots, J-I_1$, where I_1 is the nuclear spin angular momentum quantum number for the nucleus causing the largest hyperfine splittings. In the present case $I_1=1$ for ^{14}N in formamide. The quantum numbers are followed by the observed line frequency and, in parentheses, the experimentally estimated uncertainty in MHz, when available. References to the laboratory measurements are shown in the last column of the table. Opposite the $J(K_p, K_o)$ quantum numbers, the third column contains the calculated unsplit frequency and estimated uncertainty in MHz. Opposite the F quantum numbers, the calculated splittings due to the nuclear electric quadrupole interaction are listed along with their estimated uncertainties in MHz. The calculated uncertainties in both cases represent 95 percent confidence levels, which are approximately twice (this varies slightly with the number of data included in the calculation) the standard deviation obtained from the least squares analysis. The actual transition frequencies can be obtained by adding the hyperfine splittings to the unsplit frequency, and the estimated error of each is then the root-mean square of the individual estimated uncertainties.

The line strengths for the unsplit rotational transitions are shown in brackets in column 4. The relative intensities of the quadrupole components were computed from eqs (5–17) and (5–18) of Townes and Schawlow[2] and were normalized in such a way that the sum of the intensities of all components was set equal to unity. Only those hyperfine components with relative intensity ⩾ 0.01 were computed. Thus, in most instances the sum of the relative intensities may be somewhat less than unity. The total rotational energy of each rotational level was calculated using all five quartic distortion constants and all seven sextic constants. These are given in columns 5 and 6 in cm^{-1}.

As a convenience to the user, the calculated uns transition frequencies from table 13 have been lis according to increasing frequency in table 14. Seve transitions which occur between rotational levels wh energy is above the arbitrary cut-off energy of : cm^{-1} have been measured in the laboratory. Si these have been included in the analysis, they listed at the end of table 13.

3.2. Acknowledgments

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3.3. Formamide Spectral Tables

TABLE 11. Molecular parameters for formamide

Rotational constants [a]	$^{14}NH_2{}^{12}CH^{16}O$ Ref. [71B]	$^{15}NH_2{}^{12}CH^{16}O$ Ref. [60A]
A (MHz)	72716.9496 ±0.022	72448.61 ±0.80
B (MHz)	11373.4541 ±0.0039	11054.40 ±0.30
C (MHz)	9833.90416±0.0036	9589.93 ±0.30
$\Delta = I_c - I_a - I_b$ (AmuÅ^2)	+0.00601±0.00001	+0.0058±0.0010
Distortion constants [a]	**Ref. [71B]**	
τ_1 (kHz)	188.353 ±3.1	
τ_2 (kHz)	2.8776±0.44	
τ_3 (kHz)[b]	1701 ±12	
τ_{aaaa} (kHz)	−5373.00 ±15	
τ_{bbbb} (kHz)	−44.0702±0.20	
τ_{cccc} (kHz)	−18.9373±0.17	
H_J (MHz)	$(-0.9815\pm2)\times10^{-7}$	
H_{JK} (MHz)	$(+0.5787\pm6)\times10^{-6}$	
H_{KJ} (MHz)	$(-0.3260\pm0.5)\times10^{-4}$	
H_K (MHz)	$(+0.2454\pm0.4)\times10^{-3}$	
h_J (MHz)	$(+0.899\pm4)\times10^{-8}$	
h_{JK} (MHz)	$(-0.1972\pm0.3)\times10^{-5}$	
h_K (MHz)	$(+1.012\pm1.0)\times10^{-4}$	
Dipole moment	**Ref. [57A]**	
μ_a (Debye)	3.616±0.010	
μ_b (Debye)	0.852±0.010	
Quadrupole coupling constants	**Ref. [71B]**	
χ_a (MHz)	1.9797±0.03	
χ_b (MHz)	1.8722±0.02	
χ_c (MHz)	−3.8519±0.02	

Structure Ref. [60A]

r(N—H′) = 1.014±0.005 Å	∠H′NH″ = 118°53′±40′
r(N—H″) = 1.002±0.005 Å	∠H″NC = 120°37′±40′
r(N—C) = 1.376±0.010 Å	∠H′NC = 117°9′ ±40′
r(C—H) = 1.102±0.010 Å	∠NCO = 123°48′±40′
r(C=O) = 1.193±0.020 Å	∠NCH = 113°14′±40′
	∠OCH = 122°58′±40′

dihedral angles between {H′NC plane − NCO plane = 7°±5°; H″NC plane − NCH plane = 12°±5°}

[a] The number of significant figures quoted are necessary to reproduce all the calculated frequencies within their standard deviations.

[b] The value of τ_3 is set using the planarity conditions and is not, strictly speaking, a determinable parameter.

TABLE 12. The microwave spectrum of $^{15}NH_2{}^{12}CH^{16}O$

Transition Upper State	Transition Lower State	Observed frequency (est. uncertainty)	Reference
1(0, 1)	0(0, 0)	20644.37 (**)	[71D]
2(0, 2)	1(0, 1)	41262.58 (**)	[60A]
2(1, 2)	1(1, 1)	39824.21 (**)	[71D]
1(1, 1)	2(0, 2)	20131.44 (**)	[60A]
3(1, 2)	3(1, 3)	8786.69 (**)	[71D]
4(0, 4)	3(1, 3)	24470.35 (**)	[71D]
5(1, 4)	5(1, 5)	21957.87 (**)	[71D]
7(1, 6)	6(2, 5)	21933.95 (**)	[60A]

(**) Experimental uncertainties unavailable.

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$

Transition Upper state	Transition Lower state	Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹ Upper state	Energy levels in cm⁻¹ Lower state	Reference
1(1, 0)	1(1, 1)		1539.544 (.002)	[1.500]	2.805	2.754	
F = 0	F = 1	1541.018(.02)	1.458 (.021)	[.111]			71C
F = 1	F = 0	1539.570(.05)	-.027 (.023)	[.111]			71C
F = 1	F = 1	1538.135(.02)	-1.431 (.012)	[.083]			71C
F = 1	F = 2	1538.693(.02)	-.869 (.009)	[.139]			71C
F = 2	F = 1	1539.295(.02)	-.275 (.010)	[.139]			71C
F = 2	F = 2	1539.851(.02)	.286 (.002)	[.417]			71C
1(0, 1)	0(0, 0)		21207.437 (.013)	[1.000]	.707	.000	
F = 0	F = 1	21206.560(.10)	-.990 (.028)	[.111]			57A
F = 1	F = 1	21207.922(.02)	.495 (.014)	[.333]			71E
F = 2	F = 1	21207.334(.02)	-.099 (.003)	[.556]			71E
1(1, 0)	1(0, 1)		62881.707 (.040)	[1.500]	2.805	.707	
F = 0	F = 1		1.431 (.012)	[.111]			
F = 1	F = 0		.027 (.023)	[.111]			
F = 1	F = 1		-1.458 (.021)	[.083]			
F = 1	F = 2		-.864 (.007)	[.139]			
F = 2	F = 1		-.302 (.013)	[.139]			
F = 2	F = 2		.292 (.004)	[.417]			
1(1, 1)	0(0, 0)	82549.370(.17)[a]	82549.599 (.052)	[1.000]	2.754	.000	71B
F = 0	F = 1		-.936 (.020)	[.111]			
F = 1	F = 1		.468 (.010)	[.333]			
F = 2	F = 1		-.094 (.002)	[.556]			
2(1, 1)	2(1, 2)		4618.557 (.006)	[.833]	4.271	4.117	
F = 1	F = 1	4619.988(.02)	1.431 (.012)	[.150]			71A
F = 1	F = 2		-.495 (.014)	[.050]			
F = 2	F = 1		.495 (.014)	[.050]			
F = 2	F = 2	4617.118(.02)	-1.431 (.012)	[.231]			71A
F = 2	F = 3		-.193 (.010)	[.052]			
F = 3	F = 2		-.829 (.010)	[.052]			
F = 3	F = 3	4618.970(.02)	.409 (.003)	[.415]			71A
2(0, 2)	1(0, 1)	42386.070(.03 *)	42386.072 (.025)	[2.000]	2.121	.707	60A
F = 1	F = 0		.477 (.014)	[.111]			
F = 1	F = 1		-1.008 (.028)	[.083]			
F = 2	F = 1		.018 (.000)	[.250]			
F = 2	F = 2		.612 (.017)	[.083]			
F = 3	F = 2		-.047 (.001)	[.467]			
2(1, 2)	1(1, 1)	40874.910(.20 *)[a]	40875.461 (.023)	[1.500]	4.117	2.754	60A
F = 1	F = 0		-.027 (.023)	[.111]			
F = 1	F = 1		-1.431 (.012)	[.083]			
F = 2	F = 1		.495 (.014)	[.250]			
F = 2	F = 2		1.056 (.009)	[.083]			
F = 3	F = 2		-.182 (.003)	[.467]			
2(1, 1)	1(1, 0)		43954.473 (.024)	[1.500]	4.271	2.805	
F = 1	F = 0		-1.458 (.021)	[.111]			
F = 1	F = 1		1.431 (.012)	[.083]			
F = 2	F = 1		.495 (.014)	[.250]			
F = 2	F = 2		-.660 (.010)	[.083]			
F = 3	F = 2		-.059 (.004)	[.467]			
2(1, 1)	2(0, 2)		64450.108 (.039)	[2.469]	4.271	2.121	
F = 1	F = 1		.980 (.009)	[.150]			
F = 1	F = 2		-.045 (.023)	[.050]			
F = 2	F = 1		.045 (.023)	[.050]			
F = 2	F = 2		-.980 (.009)	[.231]			
F = 2	F = 3		-.321 (.013)	[.052]			
F = 3	F = 2		-.379 (.016)	[.052]			
F = 3	F = 3		.280 (.003)	[.415]			
1(1, 1)	2(0, 2)	18956.060(.04 *)	18956.091 (.023)	[.519]	2.754	2.121	60A

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition: Upper state	Transition: Lower state	Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹: Upper state	Energy levels in cm⁻¹: Lower state	Reference
F = 0	F = 1		−.423 (.032)	[.111]			
F = 1	F = 1		.980 (.009)	[.083]			
F = 1	F = 2		−.045 (.023)	[.250]			
F = 2	F = 2		−.606 (.013)	[.083]			
F = 2	F = 3		.053 (.006)	[.467]			
2(1, 2)	1(0, 1)		102217.623 (.060)	[1.500]	4.117	.707	
F = 1	F = 0		.027 (.023)	[.111]			
F = 1	F = 1		−1.458 (.021)	[.083]			
F = 2	F = 1		.468 (.010)	[.250]			
F = 2	F = 2		1.062 (.011)	[.083]			
F = 3	F = 2		−.176 (.002)	[.467]			
3(1, 2)	3(1, 3)		9236.555 (.011)	[.583]	6.470	6.162	
F = 2	F = 2		1.144 (.010)	[.212]			
F = 2	F = 3		−.821 (.019)	[.026]			
F = 3	F = 2		.535 (.019)	[.026]			
F = 3	F = 3		−1.430 (.012)	[.280]			
F = 3	F = 4		.025 (.015)	[.027]			
F = 4	F = 3		−.979 (.014)	[.027]			
F = 4	F = 4		.477 (.004)	[.402]			
3(0, 3)	2(0, 2)		63507.178 (.035)	[2.999]	4.240	2.121	
F = 2	F = 1		.081 (.003)	[.200]			
F = 2	F = 2		−.944 (.025)	[.037]			
F = 3	F = 2		.026 (.000)	[.296]			
F = 3	F = 3		.685 (.018)	[.037]			
F = 4	F = 3		−.033 (.001)	[.429]			
3(1, 3)	2(1, 2)		61295.101 (.033)	[2.667]	6.162	4.117	
F = 2	F = 1		.089 (.002)	[.200]			
F = 2	F = 2		−1.836 (.018)	[.037]			
F = 3	F = 2		.129 (.003)	[.296]			
F = 3	F = 3		1.367 (.014)	[.037]			
F = 4	F = 3		−.089 (.001)	[.429]			
3(1, 2)	2(1, 1)		65913.099 (.033)	[2.667]	6.470	4.271	
F = 2	F = 1		−.197 (.002)	[.200]			
F = 2	F = 2		.739 (.020)	[.037]			
F = 3	F = 2		.129 (.003)	[.296]			
F = 3	F = 3		−.472 (.016)	[.037]			
F = 4	F = 3		−.021 (.002)	[.429]			
3(2, 2)	2(2, 1)		63623.248 (.036)	[1.667]	12.531	10.409	
F = 2	F = 1		−.495 (.014)	[.200]			
F = 2	F = 2		.495 (.014)	[.037]			
F = 3	F = 2		.495 (.014)	[.296]			
F = 3	F = 3		−.141 (.004)	[.037]			
F = 4	F = 3		−.141 (.004)	[.429]			
3(2, 1)	2(2, 0)		63737.624 (.036)	[1.667]	12.536	10.410	
F = 2	F = 1		−.477 (.014)	[.200]			
F = 2	F = 2		.548 (.014)	[.037]			
F = 3	F = 2		.469 (.014)	[.296]			
F = 3	F = 3		−.190 (.004)	[.037]			
F = 4	F = 3		−.132 (.004)	[.429]			
3(1, 2)	3(0, 3)		66856.030 (.038)	[3.391]	6.470	4.240	
F = 2	F = 2		.702 (.006)	[.212]			
F = 2	F = 3		−.268 (.023)	[.026]			
F = 3	F = 2		.093 (.023)	[.026]			
F = 3	F = 3		−.877 (.007)	[.280]			
F = 3	F = 4		−.159 (.017)	[.027]			
F = 4	F = 3		−.426 (.018)	[.027]			
F = 4	F = 4		.292 (.002)	[.402]			
3(0, 3)	2(1, 2)		3675.627 (.020)	[1.062]	4.240	4.117	
F = 2	F = 1		.532 (.008)	[.200]			
F = 2	F = 2		−1.394 (.019)	[.037]			
F = 3	F = 2		−.424 (.010)	[.296]			
F = 3	F = 3		.814 (.016)	[.037]			
F = 4	F = 3		.095 (.003)	[.429]			
3(1, 3)	2(0, 2)		121126.653 (.068)	[2.012]	6.162	2.121	
F = 2	F = 1		−.361 (.008)	[.200]			
F = 2	F = 2		−1.386 (.022)	[.037]			
F = 3	F = 2		.579 (.007)	[.296]			
F = 3	F = 3		1.238 (.015)	[.037]			
F = 4	F = 3		−.218 (.002)	[.429]			
2(2, 0)	3(1, 3)		127362.579 (.137)	[.162]	10.410	6.162	
F = 1	F = 2		1.386 (.022)	[.200]			
F = 2	F = 2		.361 (.008)	[.037]			
F = 2	F = 3		−1.605 (.025)	[.296]			
F = 3	F = 3		−.946 (.008)	[.037]			
F = 3	F = 4		.510 (.008)	[.429]			
2(2, 1)	3(1, 2)		118097.412 (.136)	[.175]	10.409	6.470	
F = 1	F = 2		.224 (.024)	[.200]			
F = 2	F = 2		−.766 (.007)	[.037]			
F = 2	F = 3		−.156 (.026)	[.296]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition: Upper state	Transition: Lower state	Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹: Upper state	Energy levels in cm⁻¹: Lower state	Reference
F = 3	– F = 3		.480 (.009)	[.037]			
F = 3	– F = 4		.029 (.008)	[.429]			
4(1, 3)	– 4(1, 4)		15391.983 (.017)	[.450]	9.400	8.887	
F = 3	– F = 3	15392.880(.10)	1.021 (.009)	[.243]			57A
F = 3	– F = 4		–.949 (.020)	[.016]			
F = 4	– F = 3		.541 (.021)	[.016]			
F = 4	– F = 4	15390.800(.10)	–1.430 (.012)	[.301]			57A
F = 4	– F = 5		.138 (.017)	[.016]			
F = 5	– F = 4		–1.048 (.016)	[.016]			
F = 5	– F = 5	15392.710(.10)	.520 (.004)	[.391]			57A
4(0, 4)	– 3(0, 3)	84542.400(.13)	84542.374 (.044)	[3.998]	7.060	4.240	71B
F = 3	– F = 2		.021 (.001)	[.238]			
F = 3	– F = 3		–.949 (.024)	[.021]			
F = 4	– F = 3		.035 (.000)	[.313]			
F = 4	– F = 4		.754 (.019)	[.021]			
F = 5	– F = 4		–.029 (.000)	[.407]			
4(1, 4)	– 3(1, 3)	81693.540(.08)	81693.502 (.043)	[3.750]	8.887	6.162	71B
F = 3	– F = 2		.062 (.000)	[.238]			
F = 3	– F = 3		–1.913 (.021)	[.021]			
F = 4	– F = 3		.058 (.001)	[.313]			
F = 4	– F = 4		1.514 (.017)	[.021]			
F = 5	– F = 4		–.054 (.001)	[.407]			
4(1, 3)	– 3(1, 2)		87848.930 (.043)	[3.750]	9.400	6.470	
F = 3	– F = 2		–.071 (.001)	[.238]			
F = 3	– F = 3		.539 (.023)	[.021]			
F = 4	– F = 3		.058 (.001)	[.313]			
F = 4	– F = 4		–.393 (.018)	[.021]			
F = 5	– F = 4		–.011 (.001)	[.407]			
4(2, 3)	– 3(2, 2)	84807.940(.21)	84807.886 (.054)	[3.000]	15.360	12.531	71B
F = 3	– F = 2		–.144 (.004)	[.238]			
F = 3	– F = 3		–.144 (.004)	[.021]			
F = 4	– F = 3		.202 (.006)	[.313]			
F = 4	– F = 4		.202 (.006)	[.021]			
F = 5	– F = 4		–.073 (.002)	[.407]			
4(2, 2)	– 3(2, 1)		85093.364 (.053)	[3.000]	15.374	12.536	
F = 3	– F = 2		–.123 (.004)	[.238]			
F = 3	– F = 3		–.044 (.004)	[.021]			
F = 4	– F = 3		.167 (.006)	[.313]			
F = 4	– F = 4		.108 (.006)	[.021]			
F = 5	– F = 4		–.059 (.002)	[.407]			
4(3, 2)	– 3(3, 1)	84889.150(.10)	84889.136 (.084)	[1.750]	25.720	22.888	71B
F = 3	– F = 2		–.366 (.011)	[.238]			
F = 3	– F = 3		.758 (.021)	[.021]			
F = 4	– F = 3		.437 (.013)	[.313]			
F = 4	– F = 4		–.395 (.011)	[.021]			
F = 5	– F = 4		–.140 (.004)	[.407]			
4(3, 1)	– 3(3, 0)	84891.150(.10)	84891.130 (.084)	[1.750]	25.720	22.888	71B
F = 3	– F = 2		–.366 (.011)	[.238]			
F = 3	– F = 3		.758 (.021)	[.021]			
F = 4	– F = 3		.437 (.013)	[.313]			
F = 4	– F = 4		–.396 (.011)	[.021]			
F = 5	– F = 4		–.140 (.004)	[.407]			
4(1, 3)	– 4(0, 4)		70162.585 (.039)	[4.248]	9.400	7.060	
F = 3	– F = 3		.610 (.005)	[.243]			
F = 3	– F = 4		–.374 (.023)	[.016]			
F = 4	– F = 3		.130 (.023)	[.016]			
F = 4	– F = 4		–.854 (.007)	[.301]			
F = 4	– F = 5		–.072 (.019)	[.016]			
F = 5	– F = 4		–.472 (.019)	[.016]			
F = 5	– F = 5		.311 (.002)	[.391]			
4(2, 2)	– 4(1, 3)		179108.082 (.134)	[2.232]	15.374	9.400	
F = 3	– F = 3		–.288 (.006)	[.243]			
F = 3	– F = 4		.192 (.018)	[.016]			
F = 4	– F = 3		–.077 (.016)	[.016]			
F = 4	– F = 4		.403 (.009)	[.301]			
F = 4	– F = 5		.021 (.011)	[.016]			
F = 5	– F = 4		.236 (.016)	[.016]			
F = 5	– F = 5		–.147 (.003)	[.391]			
4(0, 4)	– 3(1, 3)	26924.050(.10)[a]	26922.900 (.023)	[1.640]	7.060	6.162	57A
F = 3	– F = 2		.464 (.005)	[.238]			
F = 3	– F = 3		–1.502 (.021)	[.021]			
F = 4	– F = 3		–.518 (.007)	[.313]			
F = 4	– F = 4		.938 (.017)	[.021]			
F = 5	– F = 4		.155 (.003)	[.407]			
4(1, 4)	– 3(0, 3)		139312.977 (.078)	[2.546]	8.887	4.240	
F = 3	– F = 2		–.390 (.005)	[.238]			
F = 3	– F = 3		–1.360 (.022)	[.021]			
F = 4	– F = 3		.611 (.006)	[.313]			
F = 4	– F = 4		1.329 (.017)	[.021]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition: Upper state	Transition: Lower state	Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹: Upper state	Energy levels in cm⁻¹: Lower state	Reference
3(2, 1) –	4(1, 4)		109406.701 (.121)	[.353]	12.536	8.887	
F = 2 –	F = 3		.856 (.009)	[.238]			
F = 3 –	F = 3		.777 (.009)	[.021]			
F = 3 –	F = 4		−1.194 (.013)	[.313]			
F = 4 –	F = 4		−1.135 (.013)	[.021]			
F = 4 –	F = 5		.433 (.005)	[.407]			
3(2, 2) –	4(1, 3)		93871.730 (.121)	[.400]	12.531	9.400	
F = 2 –	F = 3		−.200 (.010)	[.238]			
F = 3 –	F = 3		−.200 (.010)	[.021]			
F = 3 –	F = 4		.280 (.014)	[.313]			
F = 4 –	F = 4		.280 (.014)	[.021]			
F = 4 –	F = 5		−.102 (.005)	[.407]			
5(1, 4) –	5(1, 5)		23081.221 (.022)	[.367]	13.061	12.291	
F = 4 –	F = 4	23082.181(.02)	.953 (.008)	[.262]			71E
F = 4 –	F = 5		−1.022 (.021)	[.011]			
F = 5 –	F = 4		.545 (.021)	[.011]			
F = 5 –	F = 5	23079.785(.02)	−1.429 (.012)	[.311]			71E
F = 5 –	F = 6		.211 (.018)	[.011]			
F = 6 –	F = 5		−1.091 (.017)	[.011]			
F = 6 –	F = 6	23081.762(.02)	.550 (.005)	[.383]			71E
5(2, 3) –	5(2, 4)		997.550 (.008)	[1.461]	18.928	18.895	
F = 4 –	F = 4		.082 (.001)	[.262]			
F = 4 –	F = 5		−.431 (.014)	[.011]			
F = 5 –	F = 4		.390 (.014)	[.011]			
F = 5 –	F = 5		−.122 (.001)	[.311]			
F = 5 –	F = 6		.303 (.012)	[.011]			
F = 6 –	F = 5		−.379 (.012)	[.011]			
F = 6 –	F = 6		.047 (.000)	[.383]			
5(0, 5) –	4(0, 4)		105464.292 (.053)	[4.995]	10.578	7.060	
F = 4 –	F = 3		−.002 (.001)	[.259]			
F = 4 –	F = 4		−.986 (.023)	[.013]			
F = 5 –	F = 4		.043 (.000)	[.320]			
F = 5 –	F = 5		.826 (.019)	[.013]			
F = 6 –	F = 5		−.029 (.000)	[.394]			
5(1, 5) –	4(1, 4)		102064.353 (.058)	[4.799]	12.291	8.887	
F = 4 –	F = 3		.031 (.000)	[.259]			
F = 4 –	F = 4		−1.939 (.022)	[.013]			
F = 5 –	F = 4		.035 (.001)	[.320]			
F = 5 –	F = 5		1.603 (.018)	[.013]			
F = 6 –	F = 5		−.038 (.001)	[.394]			
5(1, 4) –	4(1, 3)		109753.591 (.057)	[4.799]	13.061	9.400	
F = 4 –	F = 3		−.037 (.000)	[.259]			
F = 4 –	F = 4		.443 (.024)	[.013]			
F = 5 –	F = 4		.036 (.001)	[.320]			
F = 5 –	F = 5		−.346 (.020)	[.013]			
F = 6 –	F = 5		−.008 (.001)	[.394]			
5(2, 4) –	4(2, 3)		105972.728 (.081)	[4.200]	18.895	15.360	
F = 4 –	F = 3		−.061 (.002)	[.259]			
F = 4 –	F = 4		−.407 (.011)	[.013]			
F = 5 –	F = 4		.105 (.003)	[.320]			
F = 5 –	F = 5		.381 (.010)	[.013]			
F = 6 –	F = 5		−.045 (.001)	[.394]			
5(2, 3) –	4(2, 2)		106541.811 (.080)	[4.200]	18.928	15.374	
F = 4 –	F = 3		−.036 (.002)	[.259]			
F = 4 –	F = 4		−.247 (.011)	[.013]			
F = 5 –	F = 4		.062 (.003)	[.320]			
F = 5 –	F = 5		.230 (.011)	[.013]			
F = 6 –	F = 5		−.026 (.001)	[.394]			
5(3, 3) –	4(3, 2)		106134.621 (.118)	[3.200]	29.260	25.720	
F = 4 –	F = 3		−.153 (.004)	[.259]			
F = 4 –	F = 4		.167 (.004)	[.013]			
F = 5 –	F = 4		.216 (.006)	[.320]			
F = 5 –	F = 5		−.039 (.000)	[.013]			
F = 6 –	F = 5		−.079 (.002)	[.394]			
5(3, 2) –	4(3, 1)		106141.594 (.118)	[3.200]	29.260	25.720	
F = 4 –	F = 3		−.152 (.004)	[.259]			
F = 4 –	F = 4		.169 (.004)	[.013]			
F = 5 –	F = 4		.215 (.006)	[.320]			
F = 5 –	F = 5		−.041 (.000)	[.013]			
F = 6 –	F = 5		−.079 (.002)	[.394]			
5(4, 2) –	4(4, 1)		106108.135 (.188)	[1.800]	43.753	40.213	
F = 4 –	F = 3		−.293 (.008)	[.259]			
F = 4 –	F = 4		.902 (.025)	[.013]			
F = 5 –	F = 4		.390 (.011)	[.320]			
F = 5 –	F = 5		−.561 (.016)	[.013]			
F = 6 –	F = 5		−.135 (.004)	[.394]			
5(4, 1) –	4(4, 0)		106108.161 (.188)	[1.800]	43.753	40.213	
F = 4 –	F = 3		−.293 (.008)	[.259]			
F = 4 –	F = 4		.902 (.025)	[.013]			
F = 5 –	F = 4		.390 (.011)	[.320]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 5 –	F = 5		–.561 (.016)	[.013]			
F = 6 –	F = 5		–.135 (.004)	[.394]			
5(1, 4) –	5(0, 5)		74451.884 (.047)	[5.021]	13.061	10.578	
F = 4 –	F = 4		.574 (.005)	[.262]			
F = 4 –	F = 5		–.454 (.023)	[.011]			
F = 5 –	F = 4		.167 (.023)	[.011]			
F = 5 –	F = 5		–.862 (.007)	[.311]			
F = 5 –	F = 6		–.007 (.019)	[.011]			
F = 6 –	F = 5		–.523 (.019)	[.011]			
F = 6 –	F = 6		.331 (.003)	[.383]			
5(2, 3) –	5(1, 4)		175896.302 (.137)	[2.946]	18.928	13.061	
F = 4 –	F = 4		–.286 (.005)	[.262]			
F = 4 –	F = 5		.121 (.020)	[.011]			
F = 5	F = 4		.022 (.018)	[.011]			
F = 5 –	F = 5		.429 (.007)	[.311]			
F = 5 –	F = 6		.091 (.014)	[.011]			
F = 6 –	F = 5		.173 (.018)	[.011]			
F = 6 –	F = 6		–.165 (.003)	[.383]			
5(0, 5) –	4(1, 4)		50693.689 (.027)	[2.260]	10.578	8.887	
F = 4 –	F = 3	50693.970(.04)	.410 (.004)	[.259]			71B
F = 4 –	F = 4		–1.561 (.022)	[.013]			
F = 5 –	F = 4	50693.170(.04)	–.532 (.006)	[.320]			71B
F = 5 –	F = 5		1.035 (.018)	[.013]			
F = 6 –	F = 5	50693.970(.04)	.181 (.002)	[.394]			71B
5(1, 5) –	4(0, 4)		156834.956 (.095)	[3.111]	12.291	7.060	
F = 4 –	F = 3		–.380 (.004)	[.259]			
F = 4 –	F = 4		–1.364 (.022)	[.013]			
F = 5 –	F = 4		.611 (.006)	[.320]			
F = 5 –	F = 5		1.393 (.018)	[.013]			
F = 6 –	F = 5		–.247 (.002)	[.394]			
4(2, 2) –	5(1, 5)		92435.711 (.104)	[.540]	15.374	12.291	
F = 3 –	F = 4		.702 (.006)	[.259]			
F = 4 –	F = 4		.913 (.014)	[.013]			
F = 4 –	F = 5		–1.062 (.009)	[.320]			
F = 5 –	F = 5		–1.229 (.015)	[.013]			
F = 5 –	F = 6		.411 (.004)	[.394]			
4(2, 3) –	5(1, 4)		68926.024 (.104)	[.654]	15.360	13.061	
F = 3 –	F = 4		–.307 (.006)	[.259]			
F = 4 –	F = 4		.039 (.015)	[.013]			
F = 4 –	F = 5		.446 (.010)	[.320]			
F = 5 –	F = 5		.171 (.016)	[.013]			
F = 5 –	F = 6		–.167 (.004)	[.394]			
6(1, 5) –	6(1, 6)		32297.269 (.026)	[.311]	17.451	16.374	
F = 5 –	F = 5	32298.190(.10)	.908 (.008)	[.274]			57A
F = 6 –	F = 6	32296.180(.10)	–1.427 (.012)	[.318]			57A
F = 7 –	F = 7	32298.190(.10)	.571 (.005)	[.377]			57A
6(2, 4) –	6(2, 5)		1987.663 (.014)	[1.229]	23.201	23.135	
F = 5 –	F = 5		.110 (.001)	[.274]			
F = 6 –	F = 6		–.174 (.001)	[.318]			
F = 7 –	F = 7		.069 (.001)	[.377]			
6(0, 6) –	5(0, 5)		126247.770 (.072)	[5.992]	14.789	10.578	
F = 5 –	F = 4		–.014 (.001)	[.273]			
F = 6 –	F = 5		.051 (.000)	[.324]			
F = 7 –	F = 6		–.030 (.000)	[.385]			
6(1, 6) –	5(1, 5)		122401.986 (.083)	[5.832]	16.374	12.291	
F = 5 –	F = 4		.019 (.000)	[.273]			
F = 6 –	F = 5		.026 (.000)	[.324]			
F = 7 –	F = 6		–.029 (.000)	[.385]			
6(1, 5) –	5(1, 4)		131618.034 (.082)	[5.832]	17.451	13.061	
F = 5 –	F = 4		–.025 (.000)	[.273]			
F = 6 –	F = 5		.028 (.000)	[.324]			
F = 7 –	F = 6		–.008 (.000)	[.385]			
6(2, 5) –	5(2, 4)		127112.854 (.125)	[5.333]	23.135	18.895	
F = 5 –	F = 4		–.032 (.001)	[.273]			
F = 6 –	F = 5		.065 (.002)	[.324]			
F = 7 –	F = 6		–.031 (.001)	[.385]			
6(2, 4) –	5(2, 3)		128102.968 (.123)	[5.333]	23.201	18.928	
F = 5 –	F = 4		–.003 (.001)	[.273]			
F = 6 –	F = 5		.014 (.002)	[.324]			
F = 7 –	F = 6		–.008 (.001)	[.385]			
6(3, 4) –	5(3, 3)		127393.783 (.175)	[4.500]	33.510	29.260	
F = 5 –	F = 4		–.076 (.002)	[.273]			
F = 6 –	F = 5		.121 (.004)	[.324]			
F = 7 –	F = 6		–.049 (.001)	[.385]			
6(3, 3) –	5(3, 2)		127412.358 (.175)	[4.500]	33.510	29.260	
F = 5 –	F = 4		–.075 (.002)	[.273]			
F = 6 –	F = 5		.119 (.004)	[.324]			
F = 7 –	F = 6		–.048 (.001)	[.385]			
6(4, 3) –	5(4, 2)		127348.647 (.224)	[3.333]	48.001	43.753	
F = 5 –	F = 4		–.150 (.004)	[.273]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 6	F = 5		.221 (.006)	[.324]			
F = 7	F = 6		-.084 (.002)	[.385]			
6(4, 2)	5(4, 1)		127348.762 (.224)	[3.333]	48.001	43.753	
F = 5	F = 4		-.150 (.004)	[.273]			
F = 6	F = 5		.221 (.006)	[.324]			
F = 7	F = 6		-.084 (.002)	[.385]			
6(5, 2)	5(5, 1)		127330.362 (.427)	[1.833]	66.628	62.381	
F = 5	F = 4		-.244 (.007)	[.273]			
F = 6	F = 5		.348 (.010)	[.324]			
F = 7	F = 6		-.128 (.004)	[.385]			
6(5, 1)	5(5, 0)		127330.362 (.427)	[1.833]	66.628	62.381	
F = 5	F = 4		-.244 (.007)	[.273]			
F = 6	F = 5		.348 (.010)	[.324]			
F = 7	F = 6		-.128 (.004)	[.385]			
6(1, 5)	6(0, 6)		79822.148 (.062)	[5.696]	17.451	14.789	
F = 5	F = 5		.563 (.005)	[.274]			
F = 6	F = 6		-.885 (.007)	[.318]			
F = 7	F = 7		.354 (.003)	[.377]			
6(2, 4)	6(1, 5)		172381.236 (.160)	[3.717]	23.201	17.451	
F = 5	F = 5		-.264 (.004)	[.274]			
F = 6	F = 6		.415 (.006)	[.318]			
F = 7	F = 7		-.166 (.002)	[.377]			
6(0, 6)	5(1, 5)		74877.107 (.036)	[2.929]	14.789	12.291	
F = 5	F = 4		.364 (.003)	[.273]			
F = 6	F = 5		-.516 (.005)	[.324]			
F = 7	F = 6		.188 (.002)	[.385]			
6(1, 6)	5(0, 5)		173772.649 (.130)	[3.714]	16.374	10.578	
F = 5	F = 4		-.359 (.004)	[.273]			
F = 6	F = 5		.594 (.006)	[.324]			
F = 7	F = 6		-.247 (.002)	[.385]			
5(2, 3)	6(1, 6)		76575.537 (.085)	[.709]	18.928	16.374	
F = 4	F = 5		.647 (.005)	[.273]			
F = 5	F = 6		-1.026 (.008)	[.324]			
F = 6	F = 7		.413 (.003)	[.385]			
5(2, 4)	6(1, 5)		43280.718 (.085)	[.931]	18.895	17.451	
F = 4	F = 5		-.343 (.005)	[.273			
F = 5	F = 6		.524 (.008)	[.324]			
F = 6	F = 7		-.205 (.003)	[.385]			
7(1, 6)	7(1, 7)		43028.126 (.029)	[.270]	22.569	21.134	
F = 6	F = 6		.876 (.007)	[.283]			
F = 7	F = 7		-1.424 (.012)	[.322]			
F = 8	F = 8		.586 (.005)	[.372]			
7(2, 5)	7(2, 6)		3557.100 (.024)	[1.058]	28.198	28.079	
F = 6	F = 6		.143 (.001)	[.283]			
F = 7	F = 7		-.232 (.002)	[.322]			
F = 8	F = 8		.095 (.001)	[.372]			
7(0, 7)	6(0, 6)		146871.639 (.107)	[6.988]	19.688	14.789	
F = 6	F = 5		-.022 (.000)	[.282]			
F = 7	F = 6		.058 (.000)	[.327]			
F = 8	F = 7		-.032 (.000)	[.378]			
7(1, 7)	6(1, 6)		142701.505 (.127)	[6.855]	21.134	16.374	
F = 6	F = 5		.011 (.000)	[.282]			
F = 7	F = 6		.023 (.000)	[.327]			
F = 8	F = 7		-.024 (.000)	[.378]			
7(1, 6)	6(1, 5)		153432.363 (.127)	[6.855]	22.569	17.451	
F = 6	F = 5		-.020 (.000)	[.282]			
F = 7	F = 6		.026 (.000)	[.327]			
F = 8	F = 7		-.008 (.000)	[.378]			
7(2, 6)	6(2, 5)		148223.377 (.192)	[6.427]	28.079	23.135	
F = 6	F = 5		-.020 (.000)	[.282]			
F = 7	F = 6		.045 (.001)	[.327]			
F = 8	F = 7		-.023 (.001)	[.378]			
7(2, 5)	6(2, 4)		149792.814 (.190)	[6.428]	28.198	23.201	
F = 6	F = 5		.012 (.000)	[.282]			
F = 7	F = 6		-.013 (.001)	[.327]			
F = 8	F = 7		.003 (.001)	[.378]			
7(3, 5)	6(3, 4)		148667.619 (.266)	[5.714]	38.469	33.510	
F = 6	F = 5		-.042 (.001)	[.282]			
F = 7	F = 6		.073 (.002)	[.327]			
F = 8	F = 7		-.032 (.001)	[.378]			
7(3, 4)	6(3, 3)		148709.342 (.265)	[5.714]	38.471	33.510	
F = 6	F = 5		-.040 (.001)	[.282]			
F = 7	F = 6		.070 (.002)	[.327]			
F = 8	F = 7		-.030 (.001)	[.378]			
7(4, 4)	6(4, 3)		148599.391 (.303)	[4.714]	52.957	48.001	
F = 6	F = 5		-.086 (.003)	[.282]			
F = 7	F = 6		.136 (.004)	[.327]			
F = 8	F = 7		-.055 (.002)	[.378]			
7(4, 3)	6(4, 2)		148599.775 (.303)	[4.714]	52.957	48.001	
F = 6	F = 5		-.086 (.003)	[.282]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 7	– F = 6		.136 (.004)	[.327]			
F = 8	– F = 7		–.055 (.002)	[.378]			
7(5, 3)	– 6(5, 2)		148567.324 (.418)	[3.429]	71.584	66.628	
F = 6	– F = 5		–.142 (.004)	[.282]			
F = 7	– F = 6		.216 (.006)	[.327]			
F = 8	– F = 7		–.084 (.002)	[.378]			
7(5, 2)	– 6(5, 1)		148567.326 (.418)	[3.429]	71.584	66.628	
F = 6	– F = 5		–.142 (.004)	[.282]			
F = 7	– F = 6		.216 (.006)	[.327]			
F = 8	– F = 7		–.084 (.002)	[.378]			
7(6, 2)	– 6(6, 1)		148556.391 (.990)	[1.857]	94.342	89.387	
F = 6	– F = 5		–.209 (.006)	[.282]			
F = 7	– F = 6		.314 (.009)	[.327]			
F = 8	– F = 7		–.120 (.003)	[.378]			
7(6, 1)	– 6(6, 0)		148556.391 (.990)	[1.857]	94.342	89.387	
F = 6	– F = 5		–.209 (.006)	[.282]			
F = 7	– F = 6		.314 (.009)	[.327]			
F = 8	– F = 7		–.120 (.003)	[.378]			
7(1, 6)	– 7(0, 7)		86382.871 (.086)	[6.258]	22.569	19.688	
F = 6	– F = 6		.564 (.005)	[.283]			
F = 7	– F = 7		.917 (.008)	[.322]			
F = 8	– F = 8		.378 (.003)	[.372]			
7(2, 5)	– 7(1, 6)		168741.687 (.212)	[4.557]	28.198	22.569	
F = 6	– F = 6		–.232 (.003)	[.283]			
F = 7	– F = 7		.376 (.005)	[.322]			
F = 8	– F = 8		–.155 (.002)	[.372]			
7(0, 7)	– 6(1, 6)		99346.760 (.054)	[3.654]	19.688	16.374	
F = 6	– F = 5		.323 (.003)	[.282]			
F = 7	– F = 6		–.484 (.005)	[.327]			
F = 8	– F = 7		.185 (.002)	[.378]			
6(2, 4)	– 7(1, 7)		61976.999 (.066)	[.850]	23.201	21.134	
F = 5	– F = 6		.633 (.005)	[.282]			
F = 6	– F = 7		–1.035 (.008)	[.327]			
F = 7	– F = 8		.428 (.003)	[.378]			
6(2, 5)	– 7(1, 6)		16961.210 (.064)	[1.232]	23.135	22.569	
F = 5	– F = 6	16960.960(.10)	–.354 (.004)	[.282]			57A
F = 6	– F = 7		.563 (.007)	[.327]			
F = 7	– F = 8	16960.960(.10)	–.227 (.003)	[.378]			57A
6(3, 3)	– 7(2, 6)		162825.254 (.356)	[.712]	33.510	28.079	
F = 5	– F = 6		.164 (.004)	[.282]			
F = 6	– F = 7		–.272 (.006)	[.327]			
F = 7	– F = 8		.114 (.003)	[.378]			
6(3, 4)	– 7(2, 5)		159240.280 (.357)	[.718]	33.510	28.198	
F = 5	– F = 6		.019 (.004)	[.282]			
F = 6	F = 7		–.037 (.006)	[.327]			
F = 7	– F = 8		.017 (.003)	[.378]			
8(1, 7)	– 8(1, 8)		55254.890 (.034)	[.239]	28.413	26.570	
F = 7	– F = 7		.851 (.007)	[.290]			
F = 8	– F = 8		–1.419 (.012)	[.324]			
F = 9	– F = 9		.597 (.005)	[.368]			
8(2, 6)	– 8(2, 7)		5878.713 (.038)	[.925]	33.923	33.726	
F = 7	– F = 7		.177 (.002)	[.290]			
F = 8	– F = 8		–.295 (.003)	[.324]			
F = 9	– F = 9		.124 (.001)	[.368]			
8(0, 8)	– 7(0, 7)		167320.928 (.167)	[7.982]	25.269	19.688	
F = 7	– F = 6		–.027 (.000)	[.289]			
F = 8	– F = 7		.064 (.001)	[.328]			
F = 9	– F = 8		–.034 (.000)	[.373]			
8(1, 8)	– 7(1, 7)		162958.903 (.195)	[7.872]	26.570	21.134	
F = 7	– F = 6		.006 (.000)	[.289]			
F = 8	– F = 7		.021 (.000)	[.328]			
F = 9	– F = 8		–.020 (.000)	[.373]			
8(1, 7)	– 7(1, 6)		175185.667 (.198)	[7.871]	28.413	22.569	
F = 7	– F = 6		–.018 (.000)	[.289]			
F = 8	– F = 7		.026 (.000)	[.328]			
F = 9	– F = 8		–.009 (.000)	[.373]			
8(2, 7)	– 7(2, 6)		169299.463 (.291)	[7.498]	33.726	28.079	
F = 7	– F = 6		–.015 (.000)	[.289]			
F = 8	– F = 7		.035 (.001)	[.328]			
F = 9	– F = 8		–.019 (.000)	[.373]			
8(2, 6)	– 7(2, 5)		171621.076 (.287)	[7.499]	33.923	28.198	
F = 7	– F = 6		.020 (.000)	[.289]			
F = 8	– F = 7		–.029 (.001)	[.328]			
F = 9	– F = 8		.010 (.000)	[.373]			
8(3, 6)	– 7(3, 5)		169956.242 (.401)	[6.875]	44.138	38.469	
F = 7	– F = 6		–.024 (.001)	[.289]			
F = 8	– F = 7		.046 (.002)	[.328]			
F = 9	– F = 8		–.021 (.001)	[.373]			
8(3, 5)	– 7(3, 4)		170039.484 (.400)	[6.875]	44.143	38.471	
F = 7	– F = 6		–.021 (.001)	[.289]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 8	F = 7		.041 (.002)	[.328]			
F = 9	F = 8		-.019 (.001)	[.373]			
8(4, 5)	7(4, 4)		169861.982 (.452)	[6.000]	58.623	52.957	
F = 7	F = 6		-.053 (.002)	[.289]			
F = 8	F = 7		.089 (.003)	[.328]			
F = 9	F = 8		-.038 (.001)	[.373]			
8(4, 4)	7(4, 3)		169863.036 (.452)	[6.000]	58.623	52.957	
F = 7	F = 6		-.052 (.002)	[.289]			
F = 8	F = 7		.089 (.003)	[.328]			
F = 9	F = 8		-.038 (.001)	[.373]			
8(5, 4)	7(5, 3)		169811.310 (.457)	[4.875]	77.248	71.584	
F = 7	F = 6		-.089 (.003)	[.289]			
F = 8	F = 7		.143 (.004)	[.328]			
F = 9	F = 8		-.059 (.002)	[.373]			
8(5, 3)	7(5, 2)		169811.316 (.457)	[4.875]	77.248	71.584	
F = 7	F = 6		-.089 (.003)	[.289]			
F = 8	F = 7		.143 (.004)	[.328]			
F = 9	F = 8		-.059 (.002)	[.373]			
8(6, 3)	7(6, 2)		169791.320 (.892)	[3.500]	100.006	94.342	
F = 7	F = 6		-.132 (.004)	[.289]			
F = 8	F = 7		.208 (.006)	[.328]			
F = 9	F = 8		-.083 (.002)	[.373]			
8(6, 2)	7(6, 1)		169791.320 (.892)	[3.500]	100.006	94.342	
F = 7	F = 6		-.132 (.004)	[.289]			
F = 8	F = 7		.208 (.006)	[.328]			
F = 9	F = 8		-.083 (.002)	[.373]			
8(7, 2)	7(7, 1)		169786.453 (2.158)	[1.875]	126.888	121.224	
F = 7	F = 6		-.183 (.005)	[.289]			
F = 8	F = 7		.285 (.008)	[.328]			
F = 9	F = 8		-.112 (.003)	[.373]			
8(7, 1)	7(7, 0)		169786.453 (2.158)	[1.875]	126.888	121.224	
F = 7	F = 6		-.183 (.005)	[.289]			
F = 8	F = 7		.285 (.008)	[.328]			
F = 9	F = 8		-.112 (.003)	[.373]			
8(1, 7)	8(0, 8)		94247.611 (.121)	[6.700]	28.413	25.269	
F = 7	F = 7		.573 (.005)	[.290]			
F = 8	F = 8		-.955 (.008)	[.324]			
F = 9	F = 9		.402 (.003)	[.368]			
8(2, 6)	8(1, 7)		165177.096 (.295)	[5.470]	33.923	28.413	
F = 7	F = 7		-.193 (.002)	[.290]			
F = 8	F = 8		.322 (.004)	[.324]			
F = 9	F = 9		-.135 (.002)	[.368]			
8(0, 8)	7(1, 7)		123966.183 (.089)	[4.437]	25.269	21.134	
F = 7	F = 6		.285 (.003)	[.289]			
F = 8	F = 7		-.443 (.004)	[.328]			
F = 9	F = 8		.175 (.002)	[.373]			
7(2, 5)	8(1, 8)		48810.911 (.049)	[.957]	28.198	26.570	
F = 6	F = 7		.638 (.005)	[.289]			
F = 7	F = 8		-1.069 (.008)	[.328]			
F = 8	F = 9		.452 (.004)	[.373]			
8(1, 7)	7(2, 6)		10001.080 (.047)	[1.556]	28.413	28.079	
F = 7	F = 6		.356 (.004)	[.289]			
F = 8	F = 7		-.582 (.006)	[.328]			
F = 9	F = 8		.241 (.003)	[.373]			
7(3, 4)	8(2, 7)		142235.132 (.299)	[.927]	38.471	33.726	
F = 6	F = 7		.139 (.003)	[.289]			
F = 7	F = 8		-.237 (.004)	[.328]			
F = 8	F = 9		.102 (.002)	[.373]			
7(3, 5)	8(2, 6)		136286.823 (.299)	[.939]	38.469	33.923	
F = 6	F = 7		-.042 (.003)	[.289]			
F = 7	F = 8		.065 (.005)	[.328]			
F = 8	F = 9		-.025 (.002)	[.373]			
9(1, 8)	9(1, 9)		68949.628 (.044)	[.215]	34.980	32.680	
F = 8	F = 8		.831 (.007)	[.295]			
F = 9	F = 9		-1.412 (.012)	[.326]			
F = 10	F = 10		.605 (.005)	[.365]			
9(2, 7)	9(2, 8)		9131.309 (.054)	[.818]	40.380	40.075	
F = 8	F = 8		.214 (.002)	[.295]			
F = 9	F = 9		-.363 (.003)	[.326]			
F = 10	F = 10		.156 (.001)	[.365]			
9(1, 8)	9(0, 9)		103524.397 (.171)	[7.019]	34.980	31.526	
F = 8	F = 8		.586 (.005)	[.295]			
F = 9	F = 9		-.995 (.008)	[.326]			
F = 10	F = 10		.427 (.004)	[.365]			
9(2, 7)	9(1, 8)		161900.180 (.415)	[6.450]	40.380	34.980	
F = 8	F = 8		-.150 (.002)	[.295]			
F = 9	F = 9		.256 (.003)	[.326]			
F = 10	F = 10		-.110 (.001)	[.365]			
9(0, 9)	8(1, 8)		148596.368 (.149)	[5.277]	31.526	26.570	
F = 8	F = 7		.248 (.002)	[.294]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 9	– F = 8		–.396 (.004)	[.329]			
F = 10	– F = 9		.160 (.002)	[.368]			
8(2, 6)	– 9(1, 9)		37260.850 (.043)	[1.026]	33.923	32.680	
F = 7	– F = 8	37261.440(.04)	.656 (.005)	[.294]			71B
F = 8	– F = 9	37259.740(.04)	–1.118 (.009)	[.329]			71B
F = 9	– F = 10	37261.440(.04)	.480 (.004)	[.368]			71B
9(1, 8)	– 8(2, 7)		37567.492 (.047)	[1.909]	34.980	33.726	
F = 8	– F = 7	37567.810(.04)	.352 (.004)	[.294]			71B
F = 9	– F = 8	37566.940(.04)	–.590 (.006)	[.329]			71B
F = 10	– F = 9	37567.810(.04)	.249 (.003)	[.368]			71B
8(3, 5)	– 9(2, 8)		121938.254 (.244)	[1.140]	44.143	40.075	
F = 7	– F = 8		.130 (.002)	[.294]			
F = 8	– F = 9		–.226 (.003)	[.329]			
F = 9	– F = 10		.099 (.002)	[.368]			
8(3, 6)	– 9(2, 7)		112654.107 (.240)	[1.164]	44.138	40.380	
F = 7	– F = 8		–.091 (.002)	[.294]			
F = 8	– F = 9		.149 (.004)	[.329]			
F = 9	– F = 10		–.062 (.002)	[.368]			
10(1, 9)	– 10(1,10)		84073.093 (.066)	[.196]	42.267	39.462	
F = 9	– F = 9	84073.760(.06)	.812 (.007)	[.299]			71B
F = 10	– F = 10	84071.680(.06)	–1.402 (.012)	[.327]			71B
F = 11	– F = 11	84073.760(.06)	.610 (.005)	[.362]			71B
10(2, 8)	– 10(2, 9)		13489.372 (.073)	[.730]	47.575	47.125	
F = 9	– F = 9		.251 (.002)	[.299]			
F = 10	– F = 10		–.433 (.004)	[.327]			
F = 11	– F = 11		.188 (.002)	[.362]			
10(3, 7)	– 10(3, 8)		564.391 (.018)	[1.706]	57.627	57.608	
F = 9	– F = 9		.016 (.000)	[.299]			
F = 10	– F = 10		–.028 (.000)	[.327]			
F = 11	– F = 11		.012 (.000)	[.362]			
10(1, 9)	– 10(0,10)		114304.453 (.238)	[7.220]	42.267	38.454	
F = 9	– F = 9		.600 (.005)	[.299]			
F = 10	– F = 10		–1.036 (.009)	[.327]			
F = 11	– F = 11		.450 (.004)	[.362]			
10(2, 8)	– 10(1, 9)		159128.042 (.573)	[7.485]	47.575	42.267	
F = 9	– F = 9		–.106 (.001)	[.299]			
F = 10	– F = 10		.182 (.002)	[.327]			
F = 11	– F = 11		–.079 (.001)	[.362]			
10(0,10)	– 9(1, 9)		173104.820 (.241)	[6.172]	38.454	32.680	
F = 9	– F = 8		.212 (.002)	[.298]			
F = 10	– F = 9		–.346 (.003)	[.330]			
F = 11	– F = 10		.143 (.001)	[.365]			
9(2, 7)	– 10(1,10)		27513.627 (.056)	[1.058]	40.380	39.462	
F = 8	– F = 9		.680 (.006)	[.298]			
F = 9	– F = 10		–1.177 (.010)	[.330]			
F = 10	– F = 11		.512 (.004)	[.365]			
10(1, 9)	– 9(2, 8)		65690.775 (.074)	[2.294]	42.267	40.075	
F = 9	– F = 8		.346 (.003)	[.298]			
F = 10	– F = 9		–.589 (.006)	[.330]			
F = 11	– F = 10		.253 (.003)	[.365]			
9(3, 6)	– 10(2, 9)		102019.695 (.192)	[1.348]	50.528	47.125	
F = 8	– F = 9		.130 (.002)	[.298]			
F = 9	– F = 10		–.229 (.003)	[.330]			
F = 10	– F = 11		.101 (.001)	[.365]			
9(3, 7)	– 10(2, 8)		88225.402 (.183)	[1.393]	50.517	47.575	
F = 8	– F = 9		–.132 (.002)	[.298]			
F = 9	– F = 10		.223 (.004)	[.330]			
F = 10	– F = 11		–.095 (.002)	[.365]			
11(1,10)	11(1,11)		100572.403 (.106)	[.181]	50.271	46.916	
F = 10	– F = 10		.794 (.007)	[.302]			
F = 11	– F = 11		–1.390 (.012)	[.328]			
F = 12	– F = 12		.611 (.005)	[.360]			
11(2, 9)	– 11(2,10)		19112.423 (.093)	[.655]	55.510	54.872	
F = 10	– F = 10		.287 (.002)	[.302]			
F = 11	– F = 11		–.503 (.004)	[.328]			
F = 12	– F = 12		.221 (.002)	[.360]			
11(3, 8)	– 11(3, 9)		983.327 (.029)	[1.552]	65.443	65.410	
F = 10	– F = 10		.023 (.000)	[.302]			
F = 11	– F = 11		–.041 (.000)	[.328]			
F = 12	– F = 12		.018 (.000)	[.360]			
11(1,10)	– 11(0,11)		126650.628 (.331)	[7.316]	50.271	46.046	
F = 10	– F = 10		.613 (.005)	[.302]			
F = 11	– F = 11		–1.073 (.009)	[.328]			
F = 12	– F = 12		.472 (.004)	[.360]			
11(2, 9)	– 11(1,10)		157072.997 (.776)	[8.553]	55.510	50.271	
F = 10	– F = 10		–.060 (.001)	[.302]			
F = 11	– F = 11		.105 (.002)	[.328]			
F = 12	– F = 12		–.046 (.001)	[.360]			
10(2, 8)	– 11(1,11)		19748.104 (.081)	[1.054]	47.575	46.916	
F = 9	– F = 10		.708 (.006)	[.302]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 10	– F = 11		-1.240 (.010)	[.331]			
F = 11	– F = 12		.546 (.004)	[.362]			
11(1,10)	– 10(2, 9)		94313.670 (.123)	[2.714]	50.271	47.125	
F = 10	– F = 9		.337 (.003)	[.302]			
F = 11	– F = 10		-.583 (.006)	[.331]			
F = 12	– F = 11		.254 (.002)	[.362]			
10(3, 7)	– 11(2,10)	82578.440(.15)	82578.363 (.146)	[1.546]	57.627	54.872	71B
F = 9	– F = 10		.137 (.001)	[.302]			
F = 10	– F = 11		-.243 (.002)	[.331]			
F = 11	– F = 12		.108 (.001)	[.362]			
10(3, 8)	– 11(2, 9)		62901.549 (.133)	[1.624]	57.608	55.510	
F = 9	– F = 10		-.167 (.002)	[.302]			
F = 10	– F = 11		.288 (.004)	[.331]			
F = 11	– F = 12		-.125 (.002)	[.362]			
12(1,11)	– 12(1,12)		118378.849 (.174)	[.169]	58.988	55.039	
F = 11	– F = 11		.776 (.007)	[.305]			
F = 12	– F = 12		-1.374 (.012)	[.329]			
F = 13	– F = 13		.610 (.005)	[.358]			
12(2,10)	– 12(2,11)		26135.729 (.112)	[.591]	64.189	63.317	
F = 11	– F = 11		.322 (.003)	[.305]			
F = 12	– F = 12		-.570 (.005)	[.329]			
F = 13	– F = 13		.254 (.002)	[.358]			
12(3, 9)	– 12(3,10)		1629.515 (.044)	[1.421]	73.978	73.924	
F = 11	– F = 11		.032 (.000)	[.305]			
F = 12	– F = 12		-.057 (.000)	[.329]			
F = 13	– F = 13		.025 (.000)	[.358]			
12(1,11)	– 12(0,12)		140587.406 (.456)	[7.325]	58.988	54.298	
F = 11	– F = 11		.624 (.005)	[.305]			
F = 12	– F = 12		-1.104 (.009)	[.329]			
F = 13	– F = 13		.491 (.004)	[.358]			
12(2,10)	– 12(1,11)		155934.702 (1.029)	[9.624]	64.189	58.988	
F = 11	– F = 11		-.014 (.000)	[.305]			
F = 12	– F = 12		.024 (.001)	[.329]			
F = 13	– F = 13		-.011 (.000)	[.358]			
11(2, 9)	– 12(1,12)		14123.729 (.114)	[1.020]	55.510	55.039	
F = 10	– F = 11		.738 (.006)	[.304]			
F = 11	– F = 12		-1.306 (.011)	[.331]			
F = 12	– F = 13		.580 (.005)	[.360]			
12(1,11)	– 11(2,10)		123367.542 (.197)	[3.176]	58.988	54.872	
F = 11	– F = 10		.326 (.003)	[.304]			
F = 12	– F = 11		-.571 (.005)	[.331]			
F = 13	– F = 12		.251 (.002)	[.360]			
11(3, 8)	– 12(2,11)		63728.074 (.109)	[1.731]	65.443	63.317	
F = 10	– F = 11		.148 (.001)	[.304]			
F = 11	– F = 12		-.266 (.002)	[.331]			
F = 12	– F = 13		.119 (.001)	[.360]			
11(3, 9)	– 12(2,10)		36609.018 (.101)	[1.860]	65.410	64.189	
F = 10	– F = 11		-.197 (.002)	[.304]			
F = 11	– F = 12		.346 (.004)	[.331]			
F = 12	– F = 13		-.152 (.002)	[.360]			
11(4, 7)	– 12(3,10)		178637.823 (.831)	[1.488]	79.882	73.924	
F = 10	– F = 11		.040 (.001)	[.304]			
F = 11	– F = 12		-.074 (.003)	[.331]			
F = 12	– F = 13		.034 (.001)	[.360]			
11(4, 8)	– 12(3, 9)		176987.836 (.847)	[1.490]	79.882	73.978	
F = 10	– F = 11		.007 (.002)	[.304]			
F = 11	– F = 12		-.016 (.003)	[.331]			
F = 12	– F = 13		.008 (.001)	[.360]			
13(1,12)	– 13(1,13)		137406.058 (.285)	[.159]	68.413	63.830	
F = 12	– F = 12		.758 (.006)	[.307]			
F = 13	– F = 13		-1.353 (.012)	[.330]			
F = 14	– F = 14		.607 (.005)	[.356]			
13(2,11)	– 13(2,12)		34663.904 (.123)	[.536]	73.613	72.457	
F = 12	– F = 12		.355 (.003)	[.307]			
F = 13	– F = 13		-.634 (.005)	[.330]			
F = 14	– F = 14		.284 (.002)	[.356]			
13(3,10)	– 13(3,11)		2588.246 (.063)	[1.308]	83.235	83.148	
F = 12	– F = 12		.043 (.000)	[.307]			
F = 13	– F = 13		-.077 (.001)	[.330]			
F = 14	– F = 14		.035 (.000)	[.356]			
13(1,12)	– 13(0,13)		156094.247 (.627)	[7.268]	68.413	63.206	
F = 12	– F = 12		.632 (.005)	[.307]			
F = 13	– F = 13		-1.129 (.010)	[.330]			
F = 14	– F = 14		.506 (.004)	[.356]			
13(2,11)	– 13(1,12)		155894.965 (1.340)	[10.665]	73.613	68.413	
F = 12	– F = 12		.031 (.000)	[.307]			
F = 13	– F = 13		-.056 (.001)	[.330]			
F = 14	– F = 14		.025 (.000)	[.356]			
12(2,10)	– 13(1,13)		10770.553 (.152)	[.962]	64.189	63.830	
F = 11	– F = 12		.767 (.006)	[.307]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 12	– F = 13		-1.370 (.011)	[.331]			
F = 13	– F = 14		.614 (.005)	[.358]			
13(1,12)	– 12(2,11)		152771.234 (.316)	[3.684]	68.413	63.317	
F = 12	– F = 11		.313 (.003)	[.307]			
F = 13	– F = 12		-.554 (.005)	[.331]			
F = 14	– F = 13		.246 (.002)	[.358]			
12(3, 9)	– 13(2,12)		45598.459 (.083)	[1.899]	73.978	72.457	
F = 11	– F = 12		.164 (.001)	[.307]			
F = 12	– F = 13		-.296 (.002)	[.331]			
F = 13	– F = 14		.134 (.001)	[.358]			
12(3,10)	– 13(2,11)		9305.041 (.105)	[2.101]	73.924	73.613	
F = 11	– F = 12		-.223 (.002)	[.307]			
F = 12	– F = 13		.395 (.004)	[.331]			
F = 13	– F = 14		-.176 (.002)	[.358]			
12(4, 8)	– 13(3,11)		157161.408 (.632)	[1.707]	88.391	83.148	
F = 11	– F = 12		.033 (.001)	[.307]			
F = 12	– F = 13		-.062 (.002)	[.331]			
F = 13	– F = 14		.029 (.001)	[.358]			
12(4, 9)	– 13(3,10)		154532.310 (.656)	[1.712]	88.389	83.235	
F = 11	– F = 12		-.011 (.001)	[.307]			
F = 12	– F = 13		.017 (.002)	[.331]			
F = 13	– F = 14		-.007 (.001)	[.358]			
14(1,13)	– 14(1,14)		157548.810 (.458)	[.152]	78.542	73.287	
F = 13	– F = 13		.738 (.006)	[.309]			
F = 14	– F = 14		-1.328 (.011)	[.330]			
F = 15	– F = 15		.600 (.005)	[.355]			
14(2,12)	– 14(2,13)		44768.185 (.123)	[.488]	83.783	82.290	
F = 13	– F = 13		.385 (.003)	[.309]			
F = 14	– F = 14		-.693 (.006)	[.330]			
F = 15	– F = 15		.313 (.003)	[.355]			
14(3,11)	– 14(3,12)		3963.449 (.086)	[1.209]	93.217	93.085	
F = 13	– F = 13		.057 (.000)	[.309]			
F = 14	– F = 14		-.102 (.001)	[.330]			
F = 15	– F = 15		.046 (.000)	[.355]			
14(1,13)	– 14(0,14)		173103.321 (.858)	[7.168]	78.542	72.768	
F = 13	– F = 13		.636 (.005)	[.309]			
F = 14	– F = 14		-1.144 (.010)	[.330]			
F = 15	– F = 15		.517 (.004)	[.355]			
14(2,12)	– 14(1,13)		157115.755 (1.717)	[11.642]	83.783	78.542	
F = 13	– F = 13		.075 (.001)	[.309]			
F = 14	– F = 14		-.136 (.001)	[.330]			
F = 15	– F = 15		.061 (.000)	[.355]			
13(2,11)	– 14(1,14)		9782.309 (.193)	[.889]	73.613	73.287	
F = 12	– F = 13		.794 (.007)	[.309]			
F = 13	– F = 14		-1.430 (.012)	[.332]			
F = 14	– F = 15		.645 (.005)	[.356]			
13(3,10)	– 14(2,13)		28335.514 (.071)	[2.044]	83.235	82.290	
F = 12	– F = 13		.184 (.001)	[.309]			
F = 13	– F = 14		.333 (.003)	[.332]			
F = 14	– F = 15		.151 (.001)	[.356]			
14(2,12)	– 13(3,11)		19020.917 (.133)	[2.351]	83.783	83.148	
F = 13	– F = 12		.244 (.002)	[.309]			
F = 14	– F = 13		-.437 (.004)	[.332]			
F = 15	– F = 14		.196 (.002)	[.356]			
13(4, 9)	– 14(3,12)		135717.641 (.453)	[1.925]	97.612	93.085	
F = 12	– F = 13		.029 (.001)	[.309]			
F = 13	– F = 14		-.054 (.002)	[.332]			
F = 14	– F = 15		.026 (.001)	[.356]			
13(4,10)	– 14(3,11)		131677.241 (.488)	[1.932]	97.609	93.217	
F = 12	– F = 13		-.029 (.001)	[.309]			
F = 13	– F = 14		.051 (.002)	[.332]			
F = 14	– F = 15		-.022 (.001)	[.356]			
15(1,14)	– 15(1,15)		178682.863 (.717)	[.146]	89.369	83.409	
F = 14	– F = 14		.717 (.006)	[.310]			
F = 15	– F = 15		-1.299 (.011)	[.331]			
F = 16	– F = 16		.590 (.005)	[.353]			
15(2,13)	– 15(2,14)		56487.148 (.110)	[.446]	94.697	92.813	
F = 14	– F = 14		.411 (.004)	[.310]			
F = 15	– F = 15		-.745 (.006)	[.331]			
F = 16	– F = 16		.339 (.003)	[.353]			
15(3,12)	– 15(3,13)		5877.781 (.111)	[1.120]	103.928	103.732	
F = 14	– F = 14		.072 (.001)	[.310]			
F = 15	– F = 15		-.131 (.001)	[.331]			
F = 16	– F = 16		.060 (.001)	[.353]			
15(2,13)	– 15(1,14)		159739.847 (2.170)	[12.524]	94.697	89.369	
F = 14	– F = 14		.118 (.001)	[.310]			
F = 15	– F = 15		-.213 (.002)	[.331]			
F = 16	– F = 16		.097 (.001)	[.353]			
14(2,12)	– 15(1,15)		11213.377 (.234)	[.808]	83.783	83.409	
F = 13	– F = 14		.819 (.007)	[.310]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole *component*	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 14	F = 15		-1.484 (.012)	[.332]			
F = 15	F = 16		.674 (.006)	[.355]			
14(3,11)	15(2,14)		12101.522 (.071)	[2.163]	93.217	92.813	
F = 13	F = 14		.207 (.002)	[.310]			
F = 14	F = 15		-.376 (.003)	[.332]			
F = 15	F = 16		.172 (.001)	[.355]			
15(2,13)	14(3,12)		48349.076 (.161)	[2.614]	94.697	93.085	
F = 14	F = 13		.261 (.003)	[.310]			
F = 15	F = 14		-.471 (.005)	[.332]			
F = 16	F = 15		.213 (.002)	[.355]			
14(4,10)	15(3,13)		114345.175 (.299)	[2.139]	107.546	103.732	
F = 13	F = 14		.027 (.001)	[.310]			
F = 14	F = 15		-.052 (.002)	[.332]			
F = 15	F = 16		.024 (.001)	[.355]			
14(4,11)	15(3,12)		108329.352 (.353)	[2.152]	107.541	103.928	
F = 13	F = 14		-.048 (.001)	[.310]			
F = 14	F = 15		.084 (.002)	[.332]			
F = 15	F = 16		-.037 (.001)	[.355]			
16(2,14)	16(2,15)		69829.817 (.124)	[.410]	106.355	104.026	
F = 15	F = 15		.434 (.004)	[.312]			
F = 16	F = 16		-.791 (.007)	[.331]			
F = 17	F = 17		.362 (.003)	[.352]			
16(3,13)	16(3,14)		8471.281 (.137)	[1.041]	115.372	115.089	
F = 15	F = 15		.091 (.001)	[.312]			
F = 16	F = 16		-.165 (.001)	[.331]			
F = 17	F = 17		.076 (.001)	[.352]			
16(2,14)	16(1,15)		163892.697 (2.711)	[13.285]	106.355	100.888	
F = 15	F = 15		.158 (.001)	[.312]			
F = 16	F = 16		-.288 (.002)	[.331]			
F = 17	F = 17		.132 (.001)	[.352]			
15(2,13)	16(1,16)		15079.417 (.268)	[.724]	94.697	94.194	
F = 14	F = 15		.840 (.007)	[.312]			
F = 15	F = 16		-1.532 (.013)	[.332]			
F = 16	F = 17		.700 (.006)	[.354]			
16(2,15)	15(3,12)		2925.992 (.075)	[2.251]	104.026	103.928	
F = 15	F = 14		-.232 (.002)	[.312]			
F = 16	F = 15		.425 (.003)	[.332]			
F = 17	F = 16		-.195 (.002)	[.354]			
16(2,14)	15(3,13)		78633.590 (.182)	[2.894]	106.355	103.732	
F = 15	F = 14		.274 (.003)	[.312]			
F = 16	F = 15		-.498 (.005)	[.332]			
F = 17	F = 16		.227 (.002)	[.354]			
15(4,11)	16(3,14)		93093.354 (.177)	[2.348]	118.195	115.089	
F = 14	F = 15		.028 (.001)	[.312]			
F = 15	F = 16		-.053 (.001)	[.332]			
F = 16	F = 17		.025 (.001)	[.354]			
15(4,12)	16(3,13)	84384.750(.21)	84384.614 (.262)	[2.370]	118.187	115.372	71B
F = 14	F = 15		-.067 (.001)	[.312]			
F = 15	F = 16		.120 (.002)	[.332]			
F = 16	F = 17		-.054 (.001)	[.354]			
17(2,15)	17(2,16)		84779.805 (.249)	[.379]	118.752	115.924	
F = 16	F = 16		.453 (.004)	[.313]			
F = 17	F = 17		-.831 (.007)	[.331]			
F = 18	F = 18		.382 (.003)	[.351]			
17(3,14)	17(3,15)		11898.239 (.158)	[.968]	127.553	127.157	
F = 16	F = 16		.111 (.001)	[.313]			
F = 17	F = 17		-.204 (.002)	[.331]			
F = 18	F = 18		.094 (.001)	[.351]			
17(4,13)	17(4,14)		632.470 (.043)	[1.800]	141.640	141.619	
F = 16	F = 16		.008 (.000)	[.313]			
F = 17	F = 17		-.015 (.000)	[.331]			
F = 18	F = 18		.007 (.000)	[.351]			
17(2,15)	17(1,16)		169683.839 (3.357)	[13.903]	118.752	113.092	
F = 16	F = 16		.196 (.002)	[.313]			
F = 17	F = 17		-.360 (.003)	[.331]			
F = 18	F = 18		.165 (.001)	[.351]			
16(2,14)	17(1,17)		21360.629 (.283)	[.643]	106.355	105.642	
F = 15	F = 16		.858 (.007)	[.313]			
F = 16	F = 17		-1.572 (.013)	[.332]			
F = 17	F = 18		.722 (.006)	[.352]			
17(2,16)	16(3,13)		16556.647 (.077)	[2.306]	115.924	115.372	
F = 16	F = 15		-.261 (.002)	[.313]			
F = 17	F = 16		.479 (.004)	[.332]			
F = 18	F = 17		-.221 (.002)	[.352]			
17(2,15)	16(3,14)		109807.732 (.238)	[3.194]	118.752	115.089	
F = 16	F = 15		.283 (.003)	[.313]			
F = 17	F = 16		-.517 (.005)	[.332]			
F = 18	F = 17		.237 (.002)	[.352]			
16(4,12)	17(3,15)		72023.227 (.088)	[2.550]	129.559	127.157	
F = 15	F = 16		.031 (.001)	[.313]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 16	– F = 17		–.058 (.001)	[.332]			
F = 17	– F = 18		.028 (.001)	[.352]			
16(4,13)	– 17(3,14)		59731.164 (.218)	[2.586]	129.546	127.553	
F = 15	– F = 16		–.086 (.001)	[.313]			
F = 16	– F = 17		.156 (.002)	[.332]			
F = 17	– F = 18		–.071 (.001)	[.352]			
18(2,16)	– 18(2,17)		101299.324 (.509)	[.352]	131.886	128.507	
F = 17	– F = 17		.469 (.004)	[.314]			
F = 18	– F = 18		–.864 (.007)	[.331]			
F = 19	– F = 19		.399 (.003)	[.350]			
18(3,15)	– 18(3,16)		16322.065 (.168)	[.901]	140.477	139.932	
F = 17	– F = 17		.134 (.001)	[.314]			
F = 18	– F = 18		–.247 (.002)	[.331]			
F = 19	– F = 19		.114 (.001)	[.350]			
18(4,14)	– 18(4,15)		987.045 (.059)	[1.696]	154.440	154.407	
F = 17	– F = 17		.011 (.000)	[.314]			
F = 18	– F = 18		–.021 (.000)	[.331]			
F = 19	– F = 19		.010 (.000)	[.350]			
18(2,16)	– 18(1,17)		177206.436 (4.126)	[14.369]	131.886	125.975	
F = 17	– F = 17		.233 (.002)	[.314]			
F = 18	– F = 18		–.428 (.004)	[.331]			
F = 19	– F = 19		.198 (.002)	[.350]			
17(2,15)	– 18(1,18)		30006.284 (.260)	[.568]	118.752	117.751	
F = 16	– F = 17		.871 (.007)	[.314]			
F = 17	– F = 18		–1.604 (.014)	[.332]			
F = 18	– F = 19		.740 (.006)	[.351]			
18(2,17)	– 17(3,14)		28591.268 (.074)	[2.324]	128.507	127.553	
F = 17	– F = 16		–.292 (.002)	[.314]			
F = 18	– F = 17		.538 (.004)	[.332]			
F = 19	– F = 18		–.249 (.002)	[.351]			
18(2,16)	– 17(3,15)		141788.831 (.422)	[3.520]	131.886	127.157	
F = 17	– F = 16		.288 (.003)	[.314]			
F = 18	– F = 17		–.529 (.005)	[.332]			
F = 19	– F = 18		.244 (.002)	[.351]			
17(4,13)	– 18(3,16)	51208.500(.03)	51208.510 (.041)	[2.744]	141.640	139.932	71B
F = 16	– F = 17		.036 (.001)	[.314]			
F = 17	– F = 18		–.068 (.001)	[.332]			
F = 18	– F = 19		.032 (.001)	[.351]			
17(4,14)	– 18(3,15)		34253.975 (.204)	[2.800]	141.619	140.477	
F = 16	– F = 17		–.106 (.001)	[.314]			
F = 17	– F = 18		.194 (.002)	[.332]			
F = 18	– F = 19		–.089 (.001)	[.351]			
17(5,12)	– 18(4,15)		172783.406 (1.768)	[2.484]	160.171	154.407	
F = 16	– F = 17		.008 (.001)	[.314]			
F = 17	– F = 18		–.016 (.002)	[.332]			
F = 18	– F = 19		.008 (.001)	[.351]			
17(5,13)	– 18(4,14)		171778.645 (1.805)	[2.486]	160.170	154.440	
F = 16	– F = 17		–.004 (.001)	[.314]			
F = 17	– F = 18		.005 (.002)	[.332]			
F = 18	– F = 19		–.002 (.001)	[.351]			
19(2,17)	– 19(2,18)		119332.312 (.925)	[.329]	145.752	141.772	
F = 18	– F = 18		.481 (.004)	[.315]			
F = 19	– F = 19		–.890 (.008)	[.332]			
F = 20	– F = 20		.413 (.004)	[.350]			
19(3,16)	– 19(3,17)		21908.265 (.157)	[.839]	154.146	153.415	
F = 18	– F = 18		.158 (.001)	[.315]			
F = 19	– F = 19		–.293 (.003)	[.332]			
F = 20	– F = 20		.136 (.001)	[.350]			
19(4,15)	– 19(4,16)		1501.250 (.077)	[1.600]	167.960	167.910	
F = 18	– F = 18		.015 (.000)	[.315]			
F = 19	– F = 19		–.029 (.000)	[.332]			
F = 20	– F = 20		.013 (.000)	[.350]			
18(2,16)	– 19(1,19)		40939.323 (.178)	[.500]	131.886	130.520	
F = 17	– F = 18	40940.240(.15)	.881 (.007)	[.315]			71B
F = 18	– F = 19	40937.760(.15)	–1.629 (.014)	[.332]			71B
F = 19	– F = 20	40940.240(.15)	.755 (.006)	[.350]			71B
19(2,18)	– 18(3,15)		38827.817 (.065)	[2.306]	141.772	140.477	
F = 18	– F = 17	38827.490(.06)	–.325 (.003)	[.315]			71B
F = 19	– F = 18	38828.420(.08)	.601 (.005)	[.332]			71B
F = 20	– F = 19	38827.490(.06)	–.279 (.002)	[.350]			71B
19(2,17)	– 18(3,16)		174482.193 (.799)	[3.877]	145.752	139.932	
F = 18	– F = 17		.291 (.003)	[.315]			
F = 19	– F = 18		–.536 (.005)	[.332]			
F = 20	– F = 19		.248 (.002)	[.350]			
18(4,14)	– 19(3,17)		30736.494 (.052)	[2.927]	154.440	153.415	
F = 17	– F = 18		.043 (.001)	[.315]			
F = 18	– F = 19		–.081 (.001)	[.332]			
F = 19	– F = 20		.038 (.000)	[.350]			
18(4,15)	– 19(3,16)		7841.184 (.190)	[3.013]	154.407	154.146	
F = 17	– F = 18		–.127 (.001)	[.315]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition		Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹		Reference
Upper state	Lower state				Upper state	Lower state	
F = 18	– F = 19		.233 (.003)	[.332]			
F = 19	– F = 20		–.107 (.001)	[.350]			
18(5,13)	– 19(4,16)		150833.212 (1.375)	[2.702]	172.942	167.910	
F = 17	– F = 18		.004 (.001)	[.315]			
F = 18	– F = 19		–.010 (.001)	[.332]			
F = 19	– F = 20		.005 (.001)	[.350]			
18(5,14)	– 19(4,15)		149300.731 (1.426)	[2.705]	172.941	167.960	
F = 17	– F = 18		–.011 (.001)	[.315]			
F = 18	– F = 19		.020 (.001)	[.332]			
F = 19	– F = 20		–.009 (.001)	[.350]			
20(2,18)	– 20(2,19)		138806.395 (1.544)	[.310]	160.346	155.716	
F = 19	– F = 19		.490 (.004)	[.316]			
F = 20	– F = 20		–.911 (.008)	[.332]			
F = 21	– F = 21		.424 (.004)	[.349]			
20(3,17)	– 20(3,18)		28816.028 (.112)	[.781]	168.564	167.603	
F = 19	– F = 19		.184 (.002)	[.316]			
F = 20	– F = 20		–.342 (.003)	[.332]			
F = 21	– F = 21		.159 (.001)	[.349]			
20(4,16)	– 20(4,17)		2230.648 (.095)	[1.513]	182.204	182.129	
F = 19	– F = 19		.021 (.000)	[.316]			
F = 20	– F = 20		–.038 (.000)	[.332]			
F = 21	– F = 21		.018 (.000)	[.349]			
19(2,17)	– 20(1,20)		54060.247 (.070)	[.439]	145.752	143.949	
F = 18	– F = 19	54061.090(.05)	.887 (.008)	[.316]			71B
F = 19	– F = 20	54058.540(.05)	–1.647 (.014)	[.332]			71B
F = 20	– F = 21	54061.090(.05)	.766 (.006)	[.350]			71B
20(2,19)	– 19(3,16)		47069.085 (.057)	[2.251]	155.716	154.146	
F = 19	– F = 18		–.359 (.003)	[.316]			
F = 20	– F = 19		.667 (.006)	[.332]			
F = 21	– F = 20		–.310 (.003)	[.350]			
19(4,15)	– 20(3,18)		10708.879 (.101)	[3.097]	167.960	167.603	
F = 18	– F = 19		.052 (.001)	[.316]			
F = 19	– F = 20		–.098 (.001)	[.332]			
F = 20	– F = 21		.046 (.000)	[.350]			
20(3,17)	– 19(4,16)		19608.400 (.160)	[3.225]	168.564	167.910	
F = 19	– F = 18		.147 (.002)	[.316]			
F = 20	– F = 19		–.272 (.003)	[.332]			
F = 21	– F = 20		.126 (.001)	[.350]			
19(5,14)	– 20(4,17)		128826.217 (1.042)	[2.918]	186.426	182.129	
F = 18	– F = 19		.002 (.001)	[.316]			
F = 19	– F = 20		–.004 (.001)	[.332]			
F = 20	– F = 21		.003 (.001)	[.350]			
19(5,15)	– 20(4,16)		126542.254 (1.110)	[2.921]	186.425	182.204	
F = 18	– F = 19		–.020 (.001)	[.316]			
F = 19	– F = 20		.035 (.001)	[.332]			
F = 20	– F = 21		–.016 (.001)	[.350]			
21(2,19)	– 21(2,20)		159633.799 (2.422)	[.293]	175.662	170.337	
F = 20	– F = 20		.497 (.004)	[.317]			
F = 21	– F = 21		–.926 (.008)	[.332]			
F = 22	– F = 22		.432 (.004)	[.348]			
21(3,18)	– 21(3,19)		37189.368 (.056)	[.727]	183.736	182.496	
F = 20	– F = 20	37189.570(.04)	.210 (.002)	[.317]			71B
F = 21	– F = 21	37188.980(.04)	–.392 (.003)	[.332]			71B
F = 22	– F = 22	37189.570(.04)	.183 (.002)	[.348]			71B
21(4,17)	– 21(4,18)		3244.410 (.111)	[1.432]	197.172	197.064	
F = 20	– F = 20		.027 (.000)	[.317]			
F = 21	– F = 21		–.050 (.000)	[.332]			
F = 22	– F = 22		.023 (.000)	[.348]			
20(2,18)	– 21(1,21)		69249.982 (.352)	[.387]	160.346	158.036	
F = 19	– F = 20		.889 (.008)	[.317]			
F = 20	– F = 21		–1.657 (.014)	[.333]			
F = 21	– F = 22		.773 (.007)	[.349]			
21(2,20)	– 20(3,17)		53131.630 (.063)	[2.165]	170.337	168.564	
F = 20	– F = 19	53131.260(.05)	–.394 (.003)	[.317]			71B
F = 21	– F = 20	53132.400(.05)	.734 (.006)	[.333]			71B
F = 22	– F = 21	53131.260(.05)	–.343 (.003)	[.349]			71B
21(3,19)	– 20(4,16)		8757.491 (.186)	[3.250]	182.496	182.204	
F = 20	– F = 19		–.063 (.001)	[.317]			
F = 21	– F = 20		.119 (.001)	[.333]			
F = 22	– F = 21		–.056 (.000)	[.349]			
21(3,18)	– 20(4,17)		48177.507 (.171)	[3.439]	183.736	182.129	
F = 20	– F = 19		.167 (.002)	[.317]			
F = 21	– F = 20		–.311 (.003)	[.333]			
F = 22	– F = 21		.145 (.001)	[.349]			
20(5,15)	– 21(4,18)		106778.801 (.761)	[3.130]	200.625	197.064	
F = 19	– F = 20		–.000 (.001)	[.317]			
F = 20	– F = 21		–.001 (.001)	[.333]			
F = 21	– F = 22		.001 (.001)	[.349]			
20(5,16)	– 21(4,17)		103445.957 (.847)	[3.136]	200.622	197.172	
F = 19	– F = 20		–.028 (.001)	[.317]			

TABLE 13. The microwave spectrum of $^{14}NH_2{}^{12}CH^{16}O$ – Continued

Transition: Upper state	Transition: Lower state	Observed frequency (estimated uncertainty)	Calculated unsplit frequency + quadrupole shifts (estimated uncertainty)	Line strength + relative intensity of quadrupole component	Energy levels in cm⁻¹: Upper state	Energy levels in cm⁻¹: Lower state	Reference
F = 20	– F = 21		.052 (.001)	[.333]			
F = 21	– F = 22		–.024 (.001)	[.349]			
22(3,19)	– 22(3,20)		47149.013 (.216)	[.677]	199.663	198.090	
F = 21	– F = 21		.236 (.002)	[.318]			
F = 22	– F = 22		–.442 (.004)	[.332]			
F = 23	– F = 23		.207 (.002)	[.347]			
21(2,19)	– 22(1,22)		86371.768 (.870)	[.343]	175.662	172.781	
F = 20	– F = 21		.888 (.008)	[.318]			
F = 21	– F = 22		–1.660 (.014)	[.333]			
F = 22	– F = 23		.777 (.007)	[.348]			
22(2,21)	– 21(3,18)		56855.013 (.088)	[2.052]	185.633	183.736	
F = 21	– F = 20		–.429 (.004)	[.318]			
F = 22	– F = 21		.802 (.007)	[.333]			
F = 23	– F = 22		–.375 (.003)	[.348]			
22(3,20)	– 21(4,17)		27530.075 (.311)	[3.384]	198.090	197.172	
F = 21	– F = 20		–.077 (.001)	[.318]			
F = 22	– F = 21		.144 (.001)	[.333]			
F = 23	– F = 22		–.068 (.001)	[.348]			
22(3,19)	– 21(4,18)		77923.498 (.352)	[3.656]	199.663	197.064	
F = 21	– F = 20		.186 (.002)	[.318]			
F = 22	– F = 21		–.348 (.003)	[.333]			
F = 23	– F = 22		.162 (.002)	[.348]			
22(2,20)	– 23(1,23)		105272.322 (1.652)	[.305]	191.694	188.182	
F = 21	– F = 22		.883 (.007)	[.319]			
F = 22	– F = 23		–1.656 (.014)	[.333]			
F = 23	– F = 24		.777 (.007)	[.348]			
23(2,22)	– 22(3,19)		58110.132 (.109)	[1.918]	201.601	199.663	
F = 22	– F = 21		–.463 (.004)	[.319]			
F = 23	– F = 22		.868 (.007)	[.333]			
F = 24	– F = 23		–.408 (.003)	[.348]			
23(5,18)	– 24(4,21)	40665.810(.03)	40665.806 (.042)	[3.739]	247.517	246.160	71B
F = 22	– F = 23		–.000 (.000)	[.319]			
F = 23	– F = 24		.000 (.001)	[.333]			
F = 24	– F = 25		.000 (.000)	[.347]			
25(2,24)	– 24(3,21)		52890.381 (.070)	[1.620]	235.548	233.783	
F = 24	– F = 23	52889.880(.06)	–.526 (.004)	[.320]			71B
F = 25	– F = 24	52891.380(.06)	.992 (.008)	[.333]			71B
F = 26	– F = 25	52889.880(.06)	–.468 (.004)	[.346]			71B
28(6,22)	– 29(5,25)	54471.510(.05)	54471.513 (.070)	[4.524]	362.439	360.622	71B
F = 27	– F = 28		–.012 (.000)	[.322]			
F = 28	– F = 29		.022 (.001)	[.333]			
F = 29	– F = 30		–.010 (.000)	[.345]			
28(6,23)	– 29(5,24)	51087.420(.04)	51087.419 (.056)	[4.530]	362.435	360.731	71B
F = 27	– F = 28		–.030 (.001)	[.322]			
F = 28	– F = 29		.057 (.001)	[.333]			
F = 29	– F = 30		–.027 (.000)	[.345]			

*See Ref. [71B].
[a]Not included in the fit.

TABLE 14. Calculated microwave transitions in $^{14}NH_2{}^{12}CH^{16}O$ (MHz)

Calculated unsplit frequency	Transition	Estimated uncertainty	Calculated unsplit frequency	Transition	Estimated uncertainty
564.391	10(3, 7) – 10(3, 8)	(.018)	10708.879	19(4,15) – 20(3,18)	(.101)
632.470	17(4,13) – 17(4,14)	(.043)	10770.553	12(2,10) – 13(1,13)	(.152)
983.327	11(3, 8) – 11(3, 9)	(.029)	11213.377	14(2,12) – 15(1,15)	(.234)
987.045	18(4,14) – 18(4,15)	(.059)	11898.239	17(3,14) – 17(3,15)	(.158)
997.550	5(2, 3) – 5(2, 4)	(.008)	12101.522	14(3,11) – 15(2,14)	(.071)
1501.250	19(4,15) – 19(4,16)	(.077)	13489.372	10(2, 8) – 10(2, 9)	(.073)
1539.544	1(1, 0) – 1(1, 1)	(.002)	14123.729	11(2, 9) – 12(1,12)	(.114)
1629.515	12(3, 9) – 12(3,10)	(.044)	15079.417	15(2,13) – 16(1,16)	(.268)
1987.663	6(2, 4) – 6(2, 5)	(.014)	15391.983	4(1, 3) – 4(1, 4)	(.017)
2230.648	20(4,16) – 20(4,17)	(.095)	16322.065	18(3,15) – 18(3,16)	(.168)
2588.246	13(3,10) – 13(3,11)	(.063)	16556.647	17(2,16) – 16(3,13)	(.077)
2925.992	16(2,15) – 15(3,12)	(.075)	16961.210	6(2, 5) – 7(1, 6)	(.064)
3244.410	21(4,17) – 21(4,18)	(.111)	18956.090	1(1, 1) – 2(0, 2)	(.023)
3557.100	7(2, 5) – 7(2, 6)	(.024)	19020.917	14(2,12) – 13(3,11)	(.133)
3675.627	3(0, 3) – 2(1, 2)	(.020)	19112.423	11(2, 9) – 11(2,10)	(.093)
3963.449	14(3,11) – 14(3,12)	(.086)	19608.400	20(3,17) – 19(4,16)	(.160)
4618.557	2(1, 1) – 2(1, 2)	(.006)	19748.104	10(2, 8) – 11(1,11)	(.081)
5877.781	15(3,12) – 15(3,13)	(.111)	21207.437	1(0, 1) – 0(0, 0)	(.013)
5878.713	8(2, 6) – 8(2, 7)	(.038)	21360.629	16(2,14) – 17(1,17)	(.283)
7841.184	18(4,15) – 19(3,16)	(.190)	21908.265	19(3,16) – 19(3,17)	(.157)
8471.280	16(3,13) – 16(3,14)	(.137)	23081.221	5(1, 4) – 5(1, 5)	(.022)
8757.491	21(3,19) – 20(4,16)	(.186)	26135.729	12(2,10) – 12(2,11)	(.112)
9131.309	9(2, 7) – 9(2, 8)	(.054)	26922.899	4(0, 4) – 3(1, 3)	(.023)
9236.555	3(1, 2) – 3(1, 3)	(.011)	27513.627	9(2, 7) – 10(1,10)	(.056)
9305.041	12(3,10) – 13(2,11)	(.105)	27530.075	22(3,20) – 21(4,17)	(.311)
9782.309	13(2,11) – 14(1,14)	(.193)	28335.514	13(3,10) – 14(2,13)	(.071)
10001.080	8(1, 7) – 7(2, 6)	(.047)	28591.268	18(2,17) – 17(3,14)	(.074)

TABLE 14. Calculated microwave transitions in $^{14}NH_2{}^{12}CH^{16}O$ (MHz)—Continued

Calculated unsplit frequency	Transition	Estimated uncertainty	Calculated unsplit frequency	Transition	Estimated uncertainty
28816.028	20(3,17) - 20(3,18)	(.112)	99346.760	7(0, 7) - 6(1, 6)	(.054)
30006.284	17(2,15) - 18(1,18)	(.260)	100572.402	11(1,10) - 11(1,11)	(.106)
30736.494	18(4,14) - 19(3,17)	(.052)	101299.324	18(2,16) - 18(2,17)	(.509)
32297.269	6(1, 5) - 6(1, 6)	(.026)	102019.694	9(3, 6) - 10(2, 9)	(.192)
34253.975	17(4,14) - 18(3,15)	(.204)	102064.353	5(1, 5) - 4(1, 4)	(.058)
34663.903	13(2,11) - 13(2,12)	(.123)	102217.623	2(1, 2) - 1(0, 1)	(.060)
36609.018	11(3, 9) - 12(2,10)	(.101)	103445.957	20(5,16) - 21(4,17)	(.847)
37189.368	21(3,18) - 21(3,19)	(.056)	103524.396	9(1, 8) - 9(0, 9)	(.171)
37260.850	8(2, 6) - 9(1, 9)	(.043)	105272.321	22(2,20) - 23(1,23)	(1.652)
37567.492	9(1, 8) - 8(2, 7)	(.047)	105464.291	5(0, 5) - 4(0, 4)	(.053)
38827.817	19(2,18) - 18(3,15)	(.065)	105972.728	5(2, 4) - 4(2, 3)	(.081)
40665.806	23(5,18) - 24(4,21)	(.042)	106108.135	5(4, 2) - 4(4, 1)	(.188)
40875.460	2(1, 2) - 1(1, 1)	(.023)	106108.160	5(4, 1) - 4(4, 0)	(.188)
40939.323	18(2,16) - 19(1,19)	(.178)	106134.620	5(3, 3) - 4(3, 2)	(.118)
42386.072	2(0, 2) - 1(0, 1)	(.025)	106141.593	5(3, 2) - 4(3, 1)	(.118)
43028.126	7(1, 6) - 7(1, 7)	(.029)	106541.811	5(2, 3) - 4(2, 2)	(.080)
43280.718	5(2, 4) - 6(1, 5)	(.085)	106778.801	20(5,15) - 21(4,18)	(.761)
43954.473	2(1, 1) - 1(1, 0)	(.024)	108329.352	14(4,11) - 15(3,12)	(.353)
44768.184	14(2,12) - 14(2,13)	(.123)	109406.700	3(2, 1) - 4(1, 4)	(.121)
45598.458	12(3, 9) - 13(2,12)	(.083)	109753.691	5(1, 4) - 4(1, 3)	(.067)
47069.085	20(2,19) - 19(3,16)	(.057)	109807.731	17(2,15) - 16(3,14)	(.238)
47149.013	22(3,19) - 22(3,20)	(.216)	112654.106	8(3, 6) - 9(2, 7)	(.240)
48177.506	21(3,18) - 20(4,17)	(.171)	114304.453	10(1, 9) - 10(0,10)	(.238)
48349.076	15(2,13) - 14(3,12)	(.161)	114345.175	14(4,10) - 15(3,13)	(.299)
48810.911	7(2, 5) - 8(1, 8)	(.049)	118097.411	2(2, 1) - 3(1, 2)	(.136)
50693.689	5(0, 5) - 4(1, 4)	(.027)	118378.849	12(1,11) - 12(1,12)	(.174)
51087.419	28(6,23) - 29(5,24)	(.056)	119332.312	19(2,17) - 19(2,18)	(.925)
51208.510	17(4,13) - 18(3,16)	(.041)	121126.652	3(1, 3) - 2(0, 2)	(.068)
52890.380	25(2,24) - 24(3,21)	(.070)	121938.254	8(3, 5) - 9(2, 8)	(.244)
53131.629	21(2,20) - 20(3,17)	(.063)	122401.985	6(1, 6) - 5(1, 5)	(.083)
54060.247	19(2,17) - 20(1,20)	(.070)	123367.542	12(1,11) - 11(2,10)	(.197)
54471.513	28(6,22) - 29(5,25)	(.070)	123966.183	8(0, 8) - 7(1, 7)	(.089)
55254.890	8(1, 7) - 8(1, 8)	(.034)	126247.770	6(0, 6) - 5(0, 5)	(.072)
56487.148	15(2,13) - 15(2,14)	(.110)	126542.254	19(5,15) - 20(4,16)	(1.110)
56855.013	22(2,21) - 21(3,18)	(.088)	126650.628	11(1,10) - 11(0,11)	(.331)
58110.132	23(2,22) - 22(3,19)	(.109)	127112.854	6(2, 5) - 5(2, 4)	(.125)
59731.164	16(4,13) - 17(3,14)	(.218)	127330.361	6(5, 1) - 5(5, 0)	(.427)
61295.101	3(1, 3) - 2(1, 2)	(.033)	127330.361	6(5, 2) - 5(5, 1)	(.427)
61976.999	6(2, 4) - 7(1, 7)	(.066)	127348.646	6(4, 3) - 5(4, 2)	(.224)
62881.706	1(1, 0) - 1(0, 1)	(.040)	127348.762	6(4, 2) - 5(4, 1)	(.224)
62901.549	10(3, 8) - 11(2, 9)	(.133)	127362.578	2(2, 0) - 3(1, 3)	(.137)
63507.178	3(0, 3) - 2(0, 2)	(.035)	127393.783	6(3, 4) - 5(3, 3)	(.175)
63623.248	3(2, 2) - 2(2, 1)	(.036)	127412.357	6(3, 3) - 5(3, 2)	(.175)
63728.074	11(3, 8) - 12(2,11)	(.109)	128102.967	6(2, 4) - 5(2, 3)	(.123)
63737.624	3(2, 1) - 2(2, 0)	(.036)	128826.216	19(5,14) - 20(4,17)	(1.042)
64450.108	2(1, 1) - 2(0, 2)	(.039)	131618.033	6(1, 5) - 5(1, 4)	(.082)
65690.774	10(1, 9) - 9(2, 8)	(.074)	131677.240	13(4,10) - 14(3,11)	(.488)
65913.099	3(1, 2) - 2(1, 1)	(.033)	135717.641	13(4, 9) - 14(3,12)	(.453)
66856.029	3(1, 2) - 3(0, 3)	(.038)	136286.822	7(3, 5) - 8(2, 6)	(.299)
68926.023	4(2, 3) - 5(1, 4)	(.104)	137406.057	13(1,12) - 13(1,13)	(.285)
68949.628	9(1, 8) - 9(1, 9)	(.044)	138806.395	20(2,18) - 20(2,19)	(1.544)
69249.981	20(2,18) - 21(1,21)	(.352)	139312.977	4(1, 4) - 3(0, 3)	(.078)
69829.816	16(2,14) - 16(2,15)	(.124)	140587.404	12(1,11) - 12(0,12)	(.456)
70162.585	4(1, 3) - 4(0, 4)	(.039)	141788.830	18(2,16) - 17(3,15)	(.422)
72023.227	16(4,12) - 17(3,15)	(.088)	142235.131	7(3, 4) - 8(2, 7)	(.299)
74451.884	5(1, 4) - 5(0, 5)	(.047)	142701.504	7(1, 7) - 6(1, 6)	(.127)
74877.106	6(0, 6) - 5(1, 5)	(.036)	146871.639	7(0, 7) - 6(0, 6)	(.107)
76575.536	5(2, 3) - 6(1, 6)	(.085)	148223.377	7(2, 6) - 6(2, 5)	(.192)
77923.498	22(3,19) - 21(4,18)	(.352)	148556.391	7(6, 1) - 6(6, 0)	(.990)
78633.589	16(2,14) - 15(3,13)	(.182)	148556.391	7(6, 2) - 6(6, 1)	(.990)
79822.147	6(1, 5) - 6(0, 6)	(.062)	148567.324	7(5, 2) - 6(5, 1)	(.418)
81693.502	4(1, 4) - 3(1, 3)	(.043)	148567.324	7(5, 3) - 6(5, 2)	(.418)
82549.599	1(1, 1) - 0(0, 0)	(.052)	148596.367	9(0, 9) - 8(1, 8)	(.149)
82578.362	10(3, 7) - 11(2,10)	(.146)	148599.391	7(4, 4) - 6(4, 3)	(.303)
84073.093	10(1, 9) - 10(1,10)	(.066)	148599.773	7(4, 3) - 6(4, 2)	(.303)
84384.614	15(4,12) - 16(3,13)	(.262)	148667.617	7(3, 5) - 6(3, 4)	(.266)
84542.374	4(0, 4) - 3(0, 3)	(.044)	148709.342	7(3, 4) - 6(3, 3)	(.265)
84779.804	17(2,15) - 17(2,16)	(.249)	149300.730	18(5,14) - 19(4,15)	(1.426)
84807.885	4(2, 3) - 3(2, 2)	(.054)	149792.812	7(2, 5) - 6(2, 4)	(.190)
84889.136	4(3, 2) - 3(3, 1)	(.084)	150833.211	18(5,13) - 19(4,16)	(1.375)
84891.130	4(3, 1) - 3(3, 0)	(.084)	152771.232	13(1,12) - 12(2,11)	(.316)
85093.363	4(2, 2) - 3(2, 1)	(.053)	153432.361	7(1, 6) - 6(1, 5)	(.127)
86371.768	21(2,19) - 22(1,22)	(.870)	154532.309	12(4, 9) - 13(3,10)	(.656)
86382.871	7(1, 6) - 7(0, 7)	(.086)	155894.965	13(2,11) - 13(1,12)	(1.340)
87848.930	4(1, 3) - 3(1, 2)	(.043)	155934.701	12(2,10) - 12(1,11)	(1.029)
88225.401	9(3, 7) - 10(2, 8)	(.183)	156094.246	13(1,12) - 13(0,13)	(.627)
92435.711	4(2, 2) - 5(1, 5)	(.104)	156834.955	5(1, 5) - 4(0, 4)	(.095)
93093.354	15(4,11) - 16(3,14)	(.177)	157072.996	11(2, 9) - 11(1,10)	(.776)
93871.729	3(2, 2) - 4(1, 3)	(.121)	157115.754	14(2,12) - 14(1,13)	(1.717)
94247.610	8(1, 7) - 8(0, 8)	(.121)	157161.408	12(4, 8) - 13(3,11)	(.632)
94313.670	11(1,10) - 10(2, 9)	(.123)	157548.809	14(1,13) - 14(1,14)	(.458)

TABLE 14. Calculated microwave transitions in $^{14}NH_2{}^{12}CH^{16}O$ (MHz)—Continued

Calculated unsplit frequency	Transition	Estimated uncertainty	Calculated unsplit frequency	Transition	Estimated uncertainty
159128.041	10(2, 8) - 10(1, 9)	(.573)	169861.980	8(4, 5) - 7(4, 4)	(.452)
159240.279	6(3, 4) - 7(2, 5)	(.357)	169863.035	8(4, 4) - 7(4, 3)	(.452)
159633.799	21(2,19) - 21(2,20)	(2.422)	169956.240	8(3, 6) - 7(3, 5)	(.401)
159739.846	15(2,13) - 15(1,14)	(2.170)	170039.482	8(3, 5) - 7(3, 4)	(.400)
161900.178	9(2, 7) - 9(1, 8)	(.415)	171621.074	8(2, 6) - 7(2, 5)	(.287)
162825.252	6(3, 3) - 7(2, 6)	(.356)	171778.645	17(5,13) - 18(4,14)	(1.805)
162958.902	8(1, 8) - 7(1, 7)	(.195)	172381.234	6(2, 4) - 6(1, 5)	(.160)
163892.695	16(2,14) - 16(1,15)	(2.711)	172783.406	17(5,12) - 18(4,15)	(1.768)
165177.096	8(2, 6) - 8(1, 7)	(.295)	173103.320	14(1,13) - 14(0,14)	(.858)
167320.926	8(0, 8) - 7(0, 7)	(.167)	173104.820	10(0,10) - 9(1, 9)	(.241)
168741.686	7(2, 5) - 7(1, 6)	(.212)	173772.648	6(1, 6) - 5(0, 5)	(.130)
169299.463	8(2, 7) - 7(2, 6)	(.291)	174482.193	19(2,17) - 18(3,16)	(.799)
169683.838	17(2,15) - 17(1,16)	(3.357)	175185.666	8(1, 7) - 7(1, 6)	(.198)
169786.453	8(7, 1) - 7(7, 0)	(2.158)	175896.301	5(2, 3) - 5(1, 4)	(.137)
169786.453	8(7, 2) - 7(7, 1)	(2.158)	176987.836	11(4, 8) - 12(3, 9)	(.847)
169791.318	8(6, 2) - 7(6, 1)	(.892)	177206.436	18(2,16) - 18(1,17)	(4.126)
169791.318	8(6, 3) - 7(6, 2)	(.892)	178637.822	11(4, 7) - 12(3,10)	(.831)
169811.309	8(5, 4) - 7(5, 3)	(.457)	178682.861	15(1,14) - 15(1,15)	(.717)
169811.314	8(5, 3) - 7(5, 2)	(.457)	179108.080	4(2, 2) - 4(1, 3)	(.134)

3.4. NH_2CHO References

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4. Thioformaldehyde

The rotational constants and centrifugal distortion constants given in table 15 for $H_2{}^{12}C^{32}S$ 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. The spectral information reported in table 17 for $H_2{}^{12}C^{32}S$ includes predicted and observed transitions between 100 MHz and 300 GHz. The predicted transitions are further limited by fixing a maximum value for the total rotational energy of the lower state of the transition at 1000 cm^{-1} for transitions up to $J=30$. Spectral data on the less abundant isotopic forms have been taken directly from the cited literature as were the structural parameters and electric dipole moment.

4.1. Organization of the Spectral Tables

Table 16 contains observed microwave transitions for $H_2{}^{12}C^{34}S$ and $H_2{}^{13}C^{32}S$. Since these data are too limited to allow a complete statistical analysis, only a few transitions of special astronomical significance have been predicted. These predictions are based on hand calculations with centrifugal distortion effects estimated by comparison with the corresponding transitions in $H_2{}^{12}C^{32}S$.

Table 17 contains the results of the statistical analysis of the reported data for $H_2{}^{12}C^{32}S$. For each spectral line the first column of table 17 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 experimentally estimated uncertainty in MHz. References to the laboratory measurements are shown in the last column of the table. Opposite the $J(K_p, K_o)$ quantum numbers, 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 number of data included in the calculation) the standard deviation obtained from the least squares analysis.

The line strengths for the rotational transitions of $H_2{}^{12}C^{32}S$ are shown in brackets in column 4 of table 17. The rotational energies are given in columns 5 and 6 in units of cm^{-1} rounded to three figures after the decimal. These rotational energies were calculated using five quartic distortion constants and one sextic constant.

As a convenience to the reader the calculated transition frequencies from table 17 are listed according to increasing frequency in table 18.

4.2. Thioformaldehyde Spectral Tables

TABLE 15. Molecular constants for thioformaldehyde

	$H_2{}^{12}C^{32}S$ [Ref. 72A]	$H_2{}^{12}C^{34}S$ [Ref. 71A]	$H_2{}^{13}C^{32}S$ [Ref. 71A]
Rotational constants [a]			
A (MHz)	291660.05 ±50		
B (MHz)	17699.5551± 0.0056	17388.31(44)	16998.70(44)
C (MHz)	16653.0621± 0.0056	16377.80(48)	16031.65(48)
Δ (amu Å^2)	+0.0606± 0.0003		
Distortion constants [a]			
τ_{aaaa} (MHz)	−139.81 ±18		
τ_{bbbb} (kHz)	−89.49296 ± 0.64		
τ_{cccc} (kHz)	−69.7911 ± 0.63		
τ_1 (MHz)	−2.321202 ± 0.0024		
τ_2 (kHz)	−0.1845614± 0.00058		
τ_3(MHz) [b]	26.82 ± 0.22		
h_{JK} (Hz)	13.18 ± 5		

Dipole moment [Ref. 71A]

$\mu_a = 1.6474(14)$ Debye
$\mu_b = \mu_c = 0$

Structure [Ref. 71A]

r_s(S=C) = 1.6108(9) Å
r_s(C—H) = 1.0929(9) Å
∠HCH = 116.87(5)°

[a] The number of significant figures quoted are necessary to reproduce all of the calculated frequencies to within their standard deviations.
[b] The value of τ_3 is set using the planarity conditions and is not, strictly speaking, a determinable parameter.

TABLE 16. Observed and calculated[a] transitions in $H_2{}^{12}C^{34}S$ and $H_2{}^{13}C^{32}S$ (MHz)

Transition Upper State	Transition Lower State	Observed frequency (est. uncertainty)	Calculated frequency (95% confidence level)	Reference
		$H_2{}^{12}C^{34}S$		
1_{10}	1_{11}	....	1011.09(0.08)	
1_{01}	0_{00}	33765.79(0.05)	33765.70(0.15)	[71A]
2_{11}	2_{12}	....	3033.18(0.15)	
2_{02}	1_{01}	67528.15(0.05)	67528.19(0.20)	[71A]
2_{12}	1_{11}	66517.88(0.05)	66517.78(0.20)	[71A]
2_{11}	1_{10}	68539.94(0.08)	68539.92(0.20)	[71A]
3_{12}	3_{13}	....	6066.22(0.20)	
4_{13}	4_{14}	....	10109.92(0.30)	
		$H_2{}^{13}C^{32}S$		
1_{10}	1_{11}	....	967.60(0.08)	
1_{01}	0_{00}	33029.96(0.10)	33029.95(0.15)	[71A]
2_{11}	2_{12}	....	2902.73(0.15)	
2_{02}	1_{01}	66057.02(0.15)	66056.95(0.20)	[71A]
2_{12}	1_{11}	65089.85(0.07)	65089.80(0.20)	[71A]
2_{11}	1_{10}	67024.96(0.05)	67025.00(0.20)	[71A]
3_{12}	3_{13}	....	5805.32(0.20)	
4_{13}	4_{14}	....	9675.12(0.30)	

[a] Calculated from observed rotational constants with corrections for centrifugal distortion extrapolated from $H_2{}^{12}C^{32}S$.

TABLE 17. The microwave spectrum of $H_2{}^{12}C^{32}S$

Transition		Observed frequency (estimated uncertainty)	Calculated frequency (estimated uncertainty)	Line strength	Energy levels in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
1(1, 0) –	1(1, 1)		1046.488 (.001)	[1.500]	10.318	10.283	
1(0, 1) –	0(0, 0)	34351.430(.020)	34351.417 (.021)	[1.000]	1.146	.000	71A
2(1, 1) –	2(1, 2)	3139.380(.030)	3139.406 (.003)	[.833]	12.644	12.540	71A
2(0, 2) –	1(0, 1)	68699.410(.100)	68699.370 (.039)	[2.000]	3.437	1.146	71A
2(1, 2) –	1(1, 1)	67653.820(.040)	67653.815 (.038)	[1.500]	12.540	10.283	71A
2(1, 1) –	1(1, 0)	69746.720(.120)	69746.732 (.038)	[1.500]	12.644	10.318	71A
3(1, 2) –	3(1, 3)	6278.650(.008)	6278.631 (.005)	[.583]	16.134	15.925	71A
3(0, 3) –	2(0, 2)	103040.220(.15)	103040.399 (.053)	[3.000]	6.874	3.437	72A
3(1, 3) –	2(1, 2)	101477.620(.12)	101477.752 (.051)	[2.667]	15.925	12.540	72A
3(1, 2) –	2(1, 1)	104617.040(.07)	104616.977 (.051)	[2.667]	16.134	12.644	72A
3(2, 2) –	2(2, 1)	103039.990(.10)	103039.845 (.054)	[1.667]	43.479	40.042	72A
3(2, 1) –	2(2, 0)	103051.810(.28)	103051.786 (.054)	[1.667]	43.479	40.042	72A
4(1, 3) –	4(1, 4)	10463.970(.005)	10463.967 (.007)	[.450]	20.787	20.438	71A
4(0, 4) –	3(0, 3)	137371.051(.30)	137371.041 (.077)	[4.000]	11.457	6.874	72A
4(1, 4) –	3(1, 3)	135297.811(.25)	135298.133 (.069)	[3.750]	20.438	15.925	72A
4(1, 3) –	3(1, 2)	139483.410(.28)	139483.469 (.069)	[3.750]	20.787	16.134	72A
4(2, 3) –	3(2, 2)	137382.029(.32)	137381.957 (.059)	[3.000]	48.062	43.479	72A
4(2, 2) –	3(2, 1)	137411.770(.25)	137411.804 (.059)	[3.000]	48.063	43.479	72A
4(3, 2) –	3(3, 1)	137369.170(.25)	137369.315 (.090)	[1.750]	93.765	89.182	72A
4(3, 1) –	3(3, 0)	137369.170(.25)	137369.347 (.090)	[1.750]	93.765	89.182	72A
5(1, 4) –	5(1, 5)	15695.120(.020)	15695.127 (.009)	[.367]	26.602	26.079	71A
5(2, 3) –	5(2, 4)		104.457 (.002)	[1.467]	53.793	53.790	
5(0, 5) –	4(0, 4)	171687.900(.52)	171687.843 (.130)	[5.000]	17.184	11.457	72A
5(1, 5) –	4(1, 4)	169113.529(.15)	169113.785 (.117)	[4.800]	26.079	20.438	72A
5(1, 4) –	4(1, 3)	174344.850(.19)	174344.945 (.117)	[4.800]	26.602	20.787	72A
5(2, 4) –	4(2, 3)	171720.230(.30)	171720.209 (.089)	[4.200]	53.790	48.062	72A
5(2, 3) –	4(2, 2)	171779.449(.35)	171779.893 (.088)	[4.200]	53.793	48.063	72A
5(3, 3) –	4(3, 2)	171710.971(.19)	171710.887 (.093)	[3.200]	99.492	93.765	72A
5(3, 2) –	4(3, 1)	171710.971(.19)	171710.998 (.093)	[3.200]	99.492	93.765	72A
5(4, 2) –	4(4, 1)	171670.650(.32)	171670.731 (.180)	[1.800]	163.378	157.652	72A
5(4, 1) –	4(4, 0)	171670.650(.32)	171670.731 (.180)	[1.800]	163.378	157.652	72A
6(1, 5) –	6(1, 6)	21971.710(.020)	21971.712 (.010)	[.310]	33.580	32.848	71A
6(2, 4) –	6(2, 5)		208.877 (.003)	[1.238]	60.670	60.663	
6(0, 6) –	5(0, 5)		205987.355 (.225)	[6.000]	24.055	17.184	
6(1, 6) –	5(1, 5)		202923.547 (.208)	[5.833]	32.848	26.079	
6(1, 5) –	5(1, 4)		209200.133 (.208)	[5.833]	33.580	26.602	
6(2, 5) –	5(2, 4)		206053.637 (.168)	[5.333]	60.663	53.790	
6(2, 4) –	5(2, 3)		206158.057 (.168)	[5.333]	60.670	53.793	
6(3, 4) –	5(3, 3)		206051.923 (.135)	[4.500]	106.365	99.492	
6(3, 3) –	5(3, 2)		206052.220 (.135)	[4.500]	106.365	99.492	
6(4, 3) –	5(4, 2)		206001.898 (.192)	[3.333]	170.250	163.378	
6(4, 2) –	5(4, 1)		206001.898 (.192)	[3.333]	170.250	163.378	
6(5, 2) –	5(5, 1)		205942.777 (.341)	[1.833]	252.221	245.352	
6(5, 1) –	5(5, 0)		205942.777 (.341)	[1.833]	252.221	245.352	
7(1, 6) –	7(1, 7)	29293.210(.020)	29293.187 (.011)	[.268]	41.721	40.744	71A
7(2, 5) –	7(2, 6)		375.888 (.005)	[1.071]	68.694	68.681	
7(0, 7) –	6(0, 6)	240266.320(.40)	240266.146 (.369)	[7.000]	32.069	24.055	72A
7(1, 7) –	6(1, 6)	236726.770(.60)	236726.273 (.348)	[6.857]	40.744	32.848	72A
7(1, 6) –	6(1, 5)	244047.840(.59)	244047.748 (.348)	[6.857]	41.721	33.580	72A
7(2, 6) –	6(2, 5)	240381.750(.34)	240381.278 (.300)	[6.429]	68.681	60.663	72A
7(2, 5) –	6(2, 4)		240548.289 (.300)	[6.429]	68.694	60.670	
7(3, 5) –	6(3, 4)		240392.288 (.242)	[5.714]	114.384	106.365	
7(3, 4) –	6(3, 3)		240392.955 (.242)	[5.714]	114.384	106.365	
7(4, 4) –	6(4, 3)	240331.430(.29)	240331.439 (.242)	[4.714]	178.266	170.250	72A
7(4, 3) –	6(4, 2)	240331.430(.29)	240331.440 (.242)	[4.714]	178.266	170.250	72A
7(5, 3) –	6(5, 2)	240261.381(.41)	240261.331 (.367)	[3.429]	260.236	252.221	72A
7(5, 2) –	6(5, 1)	240261.381(.41)	240261.331 (.367)	[3.429]	260.236	252.221	72A
7(6, 2) –	6(6, 1)		240178.630 (.585)	[1.857]	360.168	352.157	
7(6, 1) –	6(6, 0)		240178.630 (.585)	[1.857]	360.168	352.157	
8(1, 7) –	8(1, 8)	37658.830(.010)	37658.845 (.014)	[.236]	51.024	49.767	71A
8(2, 6) –	8(2, 7)		626.278 (.008)	[.944]	77.865	77.844	
8(0, 8) –	7(0, 7)		274520.803 (.568)	[8.000]	41.226	32.069	
8(1, 8) –	7(1, 7)		270520.830 (.543)	[7.875]	49.767	40.744	
8(1, 7) –	7(1, 6)		278886.489 (.543)	[7.875]	51.024	41.721	
8(2, 7) –	7(2, 6)		274702.169 (.488)	[7.500]	77.844	68.681	
8(2, 6) –	7(2, 5)		274952.558 (.488)	[7.500]	77.865	68.694	
8(3, 6) –	7(3, 5)		274731.827 (.412)	[6.875]	123.548	114.384	
8(3, 5) –	7(3, 4)		274733.162 (.412)	[6.875]	123.548	114.384	
8(4, 5) –	7(4, 4)		274659.082 (.364)	[6.000]	187.428	178.266	
8(4, 4) –	7(4, 3)		274659.085 (.364)	[6.000]	187.428	178.266	
8(5, 4) –	7(5, 3)		274577.463 (.427)	[4.875]	269.395	260.236	
8(5, 3) –	7(5, 2)		274577.463 (.427)	[4.875]	269.395	260.236	
8(6, 3) –	7(6, 2)		274482.164 (.628)	[3.500]	369.324	360.168	
8(6, 2) –	7(6, 1)		274482.164 (.628)	[3.500]	369.324	360.168	
8(7, 2) –	7(7, 1)		274371.517 (.926)	[1.875]	487.065	477.913	
8(7, 1) –	7(7, 0)		274371.517 (.926)	[1.875]	487.065	477.913	
9(1, 8) –	9(1, 9)	47067.730(.030)	47067.776 (.020)	[.211]	61.488	59.918	71A
9(2, 7) –	9(2, 8)		983.732 (.011)	[.844]	88.185	88.152	
10(1, 9) –	10(1,10)	57518.800(.050)	57518.817 (.034)	[.191]	73.114	71.195	71A
10(2, 8) –	10(2, 9)		1474.787 (.015)	[.763]	99.653	99.604	
11(1,10) –	11(1,11)	69010.610(.040)	69010.514 (.055)	[.174]	85.901	83.599	71A

TABLE 17. The microwave spectrum of $H_2{}^{12}C^{32}S$—Continued

Transition		Observed frequency (estimated uncertainty)	Calculated frequency (estimated uncertainty)	Line strength	Energy levels in cm^{-1}		Reference
Upper state	Lower state				Upper state	Lower state	
11(2, 9)	11(2,10)		2128.766 (.020)	[.696]	112.271	112.199	
12(1,11)	12(1,12)		81541.063 (.086)	[.160]	99.848	97.128	
12(2,10)	12(2,11)		2977.683 (.025)	[.639]	126.038	125.939	
13(1,12)	13(1,13)		95108.255 (.127)	[.149]	114.955	111.782	
13(2,11)	13(2,12)		4056.137 (.029)	[.591]	140.957	140.822	
14(1,13)	14(1,14)		109709.415 (.180)	[.138]	131.221	127.562	
14(2,12)	14(2,13)		5401.161 (.033)	[.550]	157.027	156.847	
15(1,14)	15(1,15)		125341.337 (.249)	[.130]	148.647	144.466	
15(2,13)	15(2,14)	7052.070(.050)	7052.044 (.036)	[.514]	174.250	174.015	71A
16(1,15)	16(1,16)		142000.207 (.335)	[.122]	167.230	162.493	
16(2,14)	16(2,15)	9050.160(.040)	9050.123 (.037)	[.482]	192.627	192.325	71A
16(3,13)	16(3,14)		143.243 (.111)	[1.091]	238.096	238.091	
17(1,16)	17(1,17)		159681.538 (.440)	[.115]	186.971	181.644	
17(2,15)	17(2,16)	11438.530(.060)	11438.524 (.036)	[.453]	212.157	211.776	71A
17(3,14)	17(3,15)		204.494 (.157)	[1.028]	257.568	257.562	
18(1,17)	18(1,18)		178380.081 (.569)	[.109]	207.868	201.918	
18(2,16)	18(2,17)	14261.900(.060)	14261.873 (.033)	[.428]	232.843	232.368	71A
18(3,15)	18(3,16)		286.071 (.218)	[.972]	278.186	278.177	
19(1,18)	19(1,19)		198089.751 (.725)	[.103]	229.921	223.313	
19(2,17)	19(2,18)	17565.920(.030)	17565.967 (.029)	[.405]	254.686	254.100	71A
19(3,16)	19(3,17)		393.008 (.296)	[.922]	299.950	299.937	
20(1,19)	20(1,20)		218803.534 (.911)	[.099]	253.129	245.830	
20(2,18)	20(2,19)	21397.440(.030)	21397.406 (.024)	[.384]	277.685	276.971	71A
20(3,17)	20(3,18)		531.204 (.395)	[.876]	322.859	322.841	
21(1,20)	21(1,21)		240513.409 (1.133)	[.094]	277.490	269.468	
21(2,19)	21(2,20)	25803.140(.030)	25803.197 (.022)	[.365]	301.843	300.982	71A
21(3,18)	21(3,19)		707.510 (.519)	[.835]	346.913	346.890	
22(1,21)	22(1,22)		263210.248 (1.394)	[.090]	303.005	294.225	
22(2,20)	22(2,21)	30830.350(.020)	30830.326 (.022)	[.347]	327.160	326.131	71A
22(3,19)	22(3,20)		929.822 (.673)	[.797]	372.113	372.082	
23(1,22)	23(1,23)		286883.732 (1.701)	[.087]	329.672	320.102	
23(2,21)	23(2,22)	36525.320(.020)	36525.325 (.026)	[.331]	353.636	352.418	71A
23(3,20)	23(3,21)		1207.168 (.861)	[.763]	398.459	398.419	
24(2,22)	24(2,23)	42933.800(.060)	42933.814 (.030)	[.316]	381.274	379.842	71A
24(3,21)	24(3,22)		1549.798 (1.089)	[.731]	425.950	425.899	
25(2,23)	25(2,24)	50100.070(.050)	50100.063 (.036)	[.302]	410.072	408.401	71A
25(3,22)	25(3,23)		1969.280 (1.361)	[.702]	454.587	454.522	
26(2,24)	26(2,25)	58066.560(.050)	58066.557 (.049)	[.289]	440.033	438.096	71A
26(3,23)	26(3,24)		2478.584 (1.685)	[.675]	484.371	484.288	
27(2,25)	27(2,26)	66873.590(.050)	66873.594 (.082)	[.277]	471.157	468.926	71A
27(3,24)	27(3,25)		3092.168 (2.066)	[.649]	515.300	515.197	
28(2,26)	28(2,27)		76558.917 (.141)	[.265]	503.443	500.889	
28(3,25)	28(3,26)		3826.061 (2.510)	[.626]	547.376	547.248	
29(2,27)	29(2,28)		87157.402 (.229)	[.255]	536.893	533.986	
29(3,26)	29(3,27)		4697.939 (3.024)	[.604]	580.598	580.442	
29(4,25)	29(4,26)		106.132 (.256)	[1.082]	644.121	644.117	
30(2,28)	30(2,29)		98700.786 (.352)	[.245]	571.506	568.214	
30(3,27)	30(3,28)		5727.191 (3.614)	[.583]	614.967	614.776	
30(4,26)	30(4,27)		138.596 (.330)	[1.046]	678.439	678.435	

TABLE 18. Calculated microwave transitions in $H_2{}^{12}C^{32}S$ (MHz)

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
104.457	5(2, 3) – 5(2, 4)	(.002)	3826.061	28(3,25) – 28(3,26)	(2.510)
106.132	29(4,25) – 29(4,26)	(.256)	4056.137	13(2,11) – 13(2,12)	(.029)
138.596	30(4,26) – 30(4,27)	(.330)	4697.939	29(3,26) – 29(3,27)	(3.024)
143.243	16(3,13) – 16(3,14)	(.111)	5401.161	14(2,12) – 14(2,13)	(.033)
204.494	17(3,14) – 17(3,15)	(.157)	5727.191	30(3,27) – 30(3,28)	(3.614)
208.877	6(2, 4) – 6(2, 5)	(.003)	6278.631	3(1, 2) – 3(1, 3)	(.005)
286.071	18(3,15) – 18(3,16)	(.218)	7052.044	15(2,13) – 15(2,14)	(.036)
375.888	7(2, 5) – 7(2, 6)	(.005)	9050.123	16(2,14) – 16(2,15)	(.037)
393.008	19(3,16) – 19(3,17)	(.296)	10463.967	4(1, 3) – 4(1, 4)	(.007)
531.204	20(3,17) – 20(3,18)	(.395)	11438.524	17(2,15) – 17(2,16)	(.036)
626.278	8(2, 6) – 8(2, 7)	(.008)	14261.873	18(2,16) – 18(2,17)	(.033)
707.510	21(3,18) – 21(3,19)	(.519)	15695.127	5(1, 4) – 5(1, 5)	(.009)
929.822	22(3,19) – 22(3,20)	(.673)	17565.967	19(2,17) – 19(2,18)	(.029)
983.732	9(2, 7) – 9(2, 8)	(.011)	21397.406	20(2,18) – 20(2,19)	(.024)
1046.488	1(1, 0) – 1(1, 1)	(.001)	21971.712	6(1, 5) – 6(1, 6)	(.010)
1207.168	23(3,20) – 23(3,21)	(.861)	25803.196	21(2,19) – 21(2,20)	(.022)
1474.787	10(2, 8) – 10(2, 9)	(.015)	29293.187	7(1, 6) – 7(1, 7)	(.011)
1549.798	24(3,21) – 24(3,22)	(1.089)	30830.326	22(2,20) – 22(2,21)	(.022)
1969.280	25(3,22) – 25(3,23)	(1.361)	34351.417	1(0, 1) – 0(0, 0)	(.021)
2128.766	11(2, 9) – 11(2,10)	(.020)	36525.324	23(2,21) – 23(2,22)	(.026)
2478.584	26(3,23) – 26(3,24)	(1.685)	37658.845	8(1, 7) – 8(1, 8)	(.014)
2977.683	12(2,10) – 12(2,11)	(.025)	42933.814	24(2,22) – 24(2,23)	(.030)
3092.168	27(3,24) – 27(3,25)	(2.066)	47067.775	9(1, 8) – 9(1, 9)	(.020)
3139.406	2(1, 1) – 2(1, 2)	(.003)	50100.063	25(2,23) – 25(2,24)	(.036)

TABLE 18. Calculated microwave transitions in $H_2{}^{12}C^{32}S$ (MHz)—Continued

Frequency	Transition	Estimated uncertainty	Frequency	Transition	Estimated uncertainty
57518.817	10(1, 9) – 10(1,10)	(.034)	205942.775	6(5, 2) – 5(5, 1)	(.341)
58066.557	26(2,24) – 26(2,25)	(.049)	205987.354	6(0, 6) – 5(0, 5)	(.225)
66873.593	27(2,25) – 27(2,26)	(.082)	206001.896	6(4, 3) – 5(4, 2)	(.192)
67653.814	2(1, 2) – 1(1, 1)	(.038)	206001.898	6(4, 2) – 5(4, 1)	(.192)
68699.370	2(0, 2) – 1(0, 1)	(.039)	206051.922	6(3, 4) – 5(3, 3)	(.135)
69010.514	11(1,10) – 11(1,11)	(.055)	206052.219	6(3, 3) – 5(3, 2)	(.135)
69746.731	2(1, 1) – 1(1, 0)	(.038)	206053.637	6(2, 5) – 5(2, 4)	(.168)
76558.917	28(2,26) – 28(2,27)	(.141)	206158.057	6(2, 4) – 5(2, 3)	(.168)
81541.062	12(1,11) – 12(1,12)	(.086)	209200.131	6(1, 5) – 5(1, 4)	(.208)
87157.401	29(2,27) – 29(2,28)	(.229)	218803.533	20(1,19) – 20(1,20)	(.911)
95108.254	13(1,12) – 13(1,13)	(.127)	236726.271	7(1, 7) – 6(1, 6)	(.348)
98700.785	30(2,28) – 30(2,29)	(.352)	240178.629	7(6, 1) – 6(6, 0)	(.585)
101477.751	3(1, 3) – 2(1, 2)	(.051)	240178.629	7(6, 2) – 6(6, 1)	(.585)
103039.845	3(2, 2) – 2(2, 1)	(.054)	240261.330	7(5, 2) – 6(5, 1)	(.367)
103040.398	3(0, 3) – 2(0, 2)	(.053)	240261.330	7(5, 3) – 6(5, 2)	(.367)
103051.785	3(2, 1) – 2(2, 0)	(.054)	240266.145	7(0, 7) – 6(0, 6)	(.369)
104616.977	3(1, 2) – 2(1, 1)	(.051)	240331.437	7(4, 4) – 6(4, 3)	(.242)
109709.415	14(1,13) – 14(1,14)	(.180)	240331.439	7(4, 3) – 6(4, 2)	(.242)
125341.336	15(1,14) – 15(1,15)	(.249)	240381.277	7(2, 6) – 6(2, 5)	(.300)
135298.131	4(1, 4) – 3(1, 3)	(.069)	240392.287	7(3, 5) – 6(3, 4)	(.242)
137369.314	4(3, 2) – 3(3, 1)	(.090)	240392.953	7(3, 4) – 6(3, 3)	(.242)
137369.346	4(3, 1) – 3(3, 0)	(.090)	240513.408	21(1,20) – 21(1,21)	(1.133)
137371.041	4(0, 4) – 3(0, 3)	(.077)	240548.289	7(2, 5) – 6(2, 4)	(.300)
137381.955	4(2, 3) – 3(2, 2)	(.059)	244047.746	7(1, 6) – 6(1, 5)	(.348)
137411.803	4(2, 2) – 3(2, 1)	(.059)	263210.246	22(1,21) – 22(1,22)	(1.394)
139483.467	4(1, 3) – 3(1, 2)	(.069)	270520.828	8(1, 8) – 7(1, 7)	(.543)
142000.207	16(1,15) – 16(1,16)	(.335)	274371.516	8(7, 1) – 7(7, 0)	(.926)
159681.537	17(1,16) – 17(1,17)	(.440)	274371.516	8(7, 2) – 7(7, 1)	(.926)
169113.783	5(1, 5) – 4(1, 4)	(.117)	274482.164	8(6, 2) – 7(6, 1)	(.628)
171670.730	5(4, 1) – 4(4, 0)	(.180)	274482.164	8(6, 3) – 7(6, 2)	(.628)
171670.730	5(4, 2) – 4(4, 1)	(.180)	274520.801	8(0, 8) – 7(0, 7)	(.568)
171687.842	5(0, 5) – 4(0, 4)	(.130)	274577.461	8(5, 3) – 7(5, 2)	(.427)
171710.885	5(3, 3) – 4(3, 2)	(.093)	274577.461	8(5, 4) – 7(5, 3)	(.427)
171710.996	5(3, 2) – 4(3, 1)	(.093)	274659.082	8(4, 4) – 7(4, 3)	(.364)
171720.207	5(2, 4) – 4(2, 3)	(.089)	274659.082	8(4, 5) – 7(4, 4)	(.364)
171779.893	5(2, 3) – 4(2, 2)	(.088)	274702.168	8(2, 7) – 7(2, 6)	(.488)
174344.943	5(1, 4) – 4(1, 3)	(.117)	274731.824	8(3, 6) – 7(3, 5)	(.412)
178380.080	18(1,17) – 18(1,18)	(.569)	274733.160	8(3, 5) – 7(3, 4)	(.412)
198089.750	19(1,18) – 19(1,19)	(.725)	274952.555	8(2, 6) – 7(2, 5)	(.488)
202923.547	6(1, 6) – 5(1, 5)	(.208)	278886.488	8(1, 7) – 7(1, 6)	(.543)
205942.775	6(5, 1) – 5(5, 0)	(.341)	286883.730	23(1,22) – 23(1,23)	(1.701)

4.3. H_2CS References

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