Microwave Spectra of Molecules of Astrophysical Interest: II Methylenimine

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William H. Kirchhoff, Donald R. Johnson, and Frank J. Lovas

Microwave Spectra of Molecules of Astrophysical Interest
II. Methylenimine

William H. Kirchhoff, Donald R. Johnson, and Frank J. Lovas

Institute for Basic Standards, National Bureau of Standards, Washington, D.C. 20234

The available data on the microwave spectrum of methylenimine are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, centrifugal distortion parameters, hyperfine coupling constants, and dipole moments are tabulated. A detailed centrifugal distortion calculation has been carried out for the most abundant isotopic form of this molecule, $H_2{}^{12}C{}^{14}NH$. Transitions have been predicted and tabulated for the frequency range 100 MHz to 300 GHz. All predicted transitions include 95 percent confidence limits; error limits have been reported for all measured transitions.

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

Contents

1. Introduction

The present tables represent the second part of a series of critical reviews [1][1] which are intended to update and revise the existing tabulated literature on molecules already identified in interstellar observations. The spectral information reported for methylenimine includes predicted as well as observed transitions between 100 MHz and 300 GHz. The reported transitions are further limited by fixing a maximum value for the total rotational energy of the lower state of the transition. This upper limit must logically vary with the molecule being reviewed and was set at 200 cm^{-1} for methylenimine. It is felt that this limit is generous enough to allow for the presentation of all transitions which might be observed by existing telescopes. The information contained in this review represents all available information on the rotational spectrum of methylenimine as of September 1, 1972.

1.1. Molecular Parameter Table

The rotational constants, centrifugal distortion constants, and quadrupole coupling constants shown in table 1 for $H_2{}^{12}C{}^{14}NH$ 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. Details of the centrifugal distortion calculation and the statistical analysis have been discussed by Kirchhoff [2]. The techniques developed for performing the least-squares analysis of the nuclear electric quadrupole hyperfine splittings in the observed spectra will be reported in a forthcoming publication [3].

1.2. Microwave Spectral Tables

Table 2 contains the results of the statistical analysis of the spectrum of $^{12}CH_2{}^{14}NH$. For each spectral line the first column of table 2 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 methylenimine. 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 unsplit frequency and estimated uncertainty in MHz. Opposite the F quantum numbers, the calculated split-

[1] Numbers in brackets indicate references in section 1.4.

tings 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 amount 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. These line strengths, denoted by ${}^{x}S(J'_{K'_p,K'_o};J''_{K''_p,K''_o})$, are defined in this review as:

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

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 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

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

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

The relative intensities of the quadrupole components shown in brackets in column 4 were computed from eqs (5–17) and (5–18) of Townes and Schawlow [4] 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 energies are given in columns 5 and 6 in cm^{-1}.

As a convenience to the user, the calculated unsplit transition frequencies from table 2 have been listed according to increasing frequency in table 3. Several transitions which occur between rotational levels whose energy is above the arbitrary cut-off energy of 200 cm^{-1} have been measured in the laboratory. Since these have been included in the analysis, they are listed at the end of table 2.

1.3. List of Symbols and Conversion Factors

a. Symbols

A, B, C	Rotational constants (MHz). $A \geq B \geq C$. ($A=h/8\pi^2 I_a$, etc.)
τ	Quartic centrifugal distortion constant (MHz).
H, h	Sextic centrifugal distortion constants (MHz).
Δ	Inertial defect (amu Å^2)$\Delta=I_c-I_a-I_b$.
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).
eQq_a, χ_a,	Nuclear electric quadrupole coupling constant along indicated principal axis (MHz).
$I_{a,b,c}$	Moments of inertia of whole molecule with respect to the indicated principal axis.
F	Total angular momentum quantum number which includes the nuclear spin for the 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:

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

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

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

1.4. References

[1] Donald R. Johnson, Frank J. Lovas, and William H. Kirchhoff, J. Chem. Phys. Ref. Data **1**, 1011 (1972).
[2] William H. Kirchhoff, J. Mol. Spectry. **41**, 333 (1972).
[3] William H. Kirchhoff and Donald R. Johnson, J. Mol. Spectry. (to be published).
[4] C. H. Townes and A. L. Schawlow, "Microwave Spectroscopy" (McGraw-Hill, New York) 1955.

2. Methylenimine Spectral Tables

TABLE 1. Molecular parameters for methylenimine

$^{12}CH_2{}^{14}NH$	
Rotational constants [a] (MHz)	Ref. [72B]
A	196211.0461 ± 0.045
B	34642.39557 ± 0.0072
C	29352.23260 ± 0.0069
$\Delta = I_c - I_a - I_b$ (amu Å^2)	0.053591 ± 0.000001
Distortion constants [a] (MHz)	Ref. [72B]
τ_1	-3.017402 ± 0.0082
τ_2	-0.4810365 ± 0.0013
τ_3 [b]	$+14.66 \pm 0.026$
τ_{aaaa}	-28.15235 ± 0.013
τ_{bbbb}	-0.3198536 ± 0.00048
τ_{cccc}	-0.1602409 ± 0.00036
H_J	$(-0.1109 \pm 0.93) \times 10^{-7}$
H_{JK}	$(+0.41472 \pm 0.27) \times 10^{-5}$
H_{KJ}	$(+0.22216 \pm 0.36) \times 10^{-4}$
H_K	$(+0.59874 \pm 0.30) \times 10^{-3}$
h_J	$(+0.4996 \pm 0.21) \times 10^{-7}$
h_{JK}	$(+0.6205 \pm 0.19) \times 10^{-5}$
h_K	$(+0.25551 \pm 0.053) \times 10^{-3}$
Dipole moment (Debye)	Ref. [72B]
μ_a	1.325 ± 0.020
μ_b	1.53 ± 0.04
Quadrupole coupling constants (MHz)	Ref. [72B]
χ_a	-0.899 ± 0.028
χ_b	-2.653 ± 0.019
χ_c	$+3.553 \pm 0.021$

[a] The number of significant figures quoted are necessary to reproduce all the calculated frequencies within their standard deviations without round-off errors.

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

TABLE 2. The microwave spectrum of methylenimine

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	
1(1, 0) −	1(1, 1)		5290.124 (.003)	[1.500]	7.700	7.524	
F = 0 −	F = 1	5288.980(0.040)	−1.113 (.023)	[.111]			72B
F = 1 −	F = 0	5289.786(0.030)	−.439 (.022)	[.111]			72B
F = 1 −	F = 1	5291.646(0.040)	1.552 (.015)	[.083]			72B
F = 1 −	F = 2	5290.726(0.040)	.756 (.011)	[.139]			72B
F = 2 −	F = 1	5290.726(0.040)	.486 (.010)	[.139]			72B
F − 2 −	F − 2	5289.786(0.030)	−.310 (.003)	[.417]			72B
1(0, 1) −	0(0, 0)		63992.999 (.031)	[1.000]	2.135	.000	
F = 0 −	F = 1	63993.332(0.085)	.450 (.029)	[.111]			72A
F = 1 −	F = 1	63992.975(0.068)	−.225 (.014)	[.333]			72A
F = 2 −	F = 1	63992.975(0.068)	.045 (.003)	[.556]			72A
1(1, 0) −	1(0, 1)		166851.817 (.078)	[1.500]	7.700	2.135	
F = 0 −	F = 1		−1.552 (.015)	[.111]			
F = 1 −	F = 0		.439 (.022)	[.111]			
F = 1 −	F = 1		1.113 (.023)	[.083]			
F = 1 −	F = 2		.843 (.009)	[.139]			
F = 2 −	F = 1		.047 (.013)	[.139]			
F = 2 −	F = 2		−.223 (.005)	[.417]			
1(1, 1) −	0(0, 0)		225554.692 (.109)	[1.000]	7.524	.000	
F = 0 −	F = 1		1.327 (.019)	[.111]			

TABLE 2. The microwave spectrum of methylenimine—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 = 1	F = 1		−.663 (.010)	[.333]			
F = 2	F = 1		.133 (.002)	[.556]			
2(1, 1)	2(1, 2)		15869.894 (.010)	[.833]	12.146	11.616	
F = 1	F = 1		−1.552 (.015)	[.150]			
F = 1	F = 2		.225 (.014)	[.050]			
F = 2	F = 1		−.225 (.014)	[.050]			
F = 2	F = 2		1.552 (.015)	[.231]			
F = 2	F = 3		.410 (.010)	[.052]			
F = 3	F = 2		.699 (.011)	[.052]			
F = 3	F = 3		−.443 (.004)	[.415]			
2(2, 0)	2(2, 1)		127.709 (.000)	[3.333]	28.314	28.310	
F = 1	F = 1		−.025 (.000)	[.150]			
F = 1	F = 2		−.475 (.029)	[.050]			
F = 2	F = 1		.475 (.029)	[.050]			
F = 2	F = 2		.025 (.000)	[.231]			
F = 2	F = 3		.314 (.018)	[.052]			
F = 3	F = 2		−.296 (.018)	[.052]			
F = 3	F = 3		−.007 (.000)	[.415]			
2(0, 2)	1(0, 1)		127856.850 (.062)	[2.000]	6.399	2.135	
F = 1	F = 0		−.200 (.014)	[.111]			
F = 1	F = 1		.475 (.029)	[.083]			
F = 2	F = 1		−.025 (.000)	[.250]			
F = 2	F = 2		−.295 (.017)	[.083]			
F = 3	F = 2		.026 (.001)	[.467]			
2(1, 2)	1(1, 1)	122692.320(0.38)	122692.377 (.069)	[1.500]	11.616	7.524	72A
F = 1	F = 0		−.439 (.022)	[.111]			
F = 1	F = 1		1.552 (.015)	[.083]			
F = 2	F = 1		−.225 (.014)	[.250]			
F = 2	F = 2		−1.021 (.011)	[.083]			
F = 3	F = 2		.121 (.004)	[.467]			
2(1, 1)	1(1, 0)		133272.146 (.068)	[1.500]	12.146	7.700	
F = 1	F = 0		1.113 (.023)	[.111]			
F = 1	F = 1		−1.552 (.015)	[.083]			
F = 2	F = 1		−.225 (.014)	[.250]			
F = 2	F = 2		.841 (.010)	[.083]			
F = 3	F = 2		−.012 (.003)	[.467]			
2(1, 1)	2(0, 2)		172267.113 (.083)	[2.459]	12.146	6.399	
F = 1	F = 1		−.913 (.011)	[.150]			
F = 1	F = 2		−.414 (.022)	[.050]			
F = 2	F = 1		.414 (.022)	[.050]			
F = 2	F = 2		.913 (.011)	[.231]			
F = 2	F = 3		.592 (.013)	[.052]			
F = 3	F = 2		.060 (.016)	[.052]			
F = 3	F = 3		−.261 (.003)	[.415]			
1(1, 1)	2(0, 2)		33704.843 (.018)	[.524]	7.524	6.399	
F = 0	F = 1	33705.893(0.045)	1.077 (.031)	[.111]			72B
F = 1	F = 1	33703.904(0.045)	−.913 (.011)	[.083]			72B
F = 1	F = 2	33704.390(0.045)	−.414 (.022)	[.250]			72B
F = 2	F = 2	33705.290(0.072)	.382 (.013)	[.083]			72B
F = 2	F = 3	33704.885(0.045)	.061 (.006)	[.467]			72B
2(1, 2)	1(0, 1)		284254.069 (.146)	[1.500]	11.616	2.135	
F = 1	F = 0		.439 (.022)	[.111]			
F = 1	F = 1		1.113 (.023)	[.083]			
F = 2	F = 1		−.663 (.010)	[.250]			
F = 2	F = 2		−.933 (.013)	[.083]			
F = 3	F = 2		.209 (.002)	[.467]			
3(1, 2)	3(1, 3)		31736.427 (.017)	[.583]	18.811	17.752	
F = 2	F = 2	31735.172(0.027)	−1.241 (.012)	[.212]			72B
F = 2	F = 3		.473 (.020)	[.026]			
F = 3	F = 2		−.162 (.019)	[.026]			
F = 3	F = 3	31737.971(0.027)	1.551 (.015)	[.280]			72B
F = 3	F = 4		.282 (.015)	[.027]			
F = 4	F = 3		.752 (.016)	[.027]			
F = 4	F = 4	31735.928(0.027)	−.517 (.005)	[.402]			72B
3(2, 1)	3(2, 2)		638.004 (.001)	[2.331]	34.735	34.713	
F = 2	F = 2		−.050 (.000)	[.212]			
F = 2	F = 3		−.050 (.000)	[.026]			
F = 3	F = 2		.062 (.001)	[.026]			
F = 3	F = 3		.062 (.001)	[.280]			
F = 3	F = 4		.062 (.001)	[.027]			
F = 4	F = 3		−.021 (.000)	[.027]			
F = 4	F = 4		−.021 (.000)	[.402]			
3(0, 3)	2(0, 2)		191462.942 (.098)	[2.998]	12.786	6.399	
F = 2	F = 1		−.020 (.003)	[.200]			
F = 2	F = 2		.479 (.026)	[.037]			
F = 3	F = 2		−.037 (.000)	[.296]			
F = 3	F = 3		−.358 (.018)	[.037]			
F = 4	F = 3		.024 (.001)	[.429]			
3(1, 3)	2(1, 2)		183956.852 (.110)	[2.667]	17.752	11.616	
F = 2	F = 1		−.127 (.002)	[.200]			

TABLE 2. The microwave spectrum of methylenimine—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 = 2	F = 2		1.650 (.022)	[.037]			
F = 3	F = 2		-.064 (.004)	[.296]			
F = 3	F = 3		-1.206 (.017)	[.037]			
F = 4	F = 3		.064 (.002)	[.429]			
3(1, 2)	2(1, 1)		199823.385 (.108)	[2.667]	18.811	12.146	
F = 2	F = 1		.184 (.002)	[.200]			
F = 2	F = 2		-1.143 (.019)	[.037]			
F = 3	F = 2		-.064 (.004)	[.296]			
F = 3	F = 3		.789 (.015)	[.037]			
F = 4	F = 3		-.010 (.002)	[.429]			
3(2, 2)	2(2, 1)		191959.458 (.155)	[1.667]	34.713	28.310	
F = 2	F = 1		.225 (.014)	[.200]			
F = 2	F = 2		-.225 (.014)	[.037]			
F = 3	F = 2		-.225 (.014)	[.296]			
F = 3	F = 3		.064 (.004)	[.037]			
F = 4	F = 3		.064 (.004)	[.429]			
3(2, 1)	2(2, 0)		192469.753 (.155)	[1.667]	34.735	28.314	
F = 2	F = 1		.200 (.014)	[.200]			
F = 2	F = 2		-.299 (.014)	[.037]			
F = 3	F = 2		-.188 (.014)	[.296]			
F = 3	F = 3		.133 (.004)	[.037]			
F = 4	F = 3		.051 (.004)	[.429]			
3(1, 2)	3(0, 3)		180627.556 (.093)	[3.358]	18.811	12.786	
F = 2	F = 2		-.709 (.007)	[.212]			
F = 2	F = 3		-.192 (.023)	[.026]			
F = 3	F = 2		.370 (.022)	[.026]			
F = 3	F = 3		.886 (.009)	[.280]			
F = 3	F = 4		.504 (.016)	[.027]			
F = 4	F = 3		.087 (.018)	[.027]			
F = 4	F = 4		-.295 (.003)	[.402]			
3(0, 3)	2(1, 2)		35065.723 (.017)	[1.081]	12.786	11.616	
F = 2	F = 1	35065.090(0.05)	-.659 (.008)	[.200]			72B
F = 2	F = 2	35066.830(0.05)	1.118 (.021)	[.037]			72B
F = 3	F = 2	35066.350(0.04)	.601 (.009)	[.296]			72B
F = 3	F = 3		-.541 (.017)	[.037]			
F = 4	F = 3	35065.550(0.03)	-.158 (.003)	[.429]			72B
2(2, 1)	3(1, 2)		284778.233 (.106)	[.177]	28.310	18.811	
F = 1	F = 2		.255 (.023)	[.200]			
F = 2	F = 2		.704 (.009)	[.037]			
F = 2	F = 3		-.374 (.025)	[.296]			
F = 3	F = 3		-.663 (.009)	[.037]			
F = 3	F = 4		.136 (.008)	[.429]			
4(1, 3)	4(1, 4)		52880.592 (.024)	[.450]	27.693	25.929	
F = 3	F = 3	52879.454(0.07)	-1.107 (.010)	[.243]			72B
F = 3	F = 4		.583 (.021)	[.016]			
F = 4	F = 3		-.140 (.021)	[.016]			
F = 4	F = 4	52882.142(0.07)	1.550 (.015)	[.301]			72B
F = 4	F = 5		.206 (.017)	[.016]			
F = 5	F = 4		.781 (.018)	[.016]			
F = 5	F = 5	52880.028(0.07)	-.564 (.005)	[.391]			72B
4(2, 2)	4(2, 3)		1910.327 (.002)	[1.795]	43.311	43.247	
F = 3	F = 3		-.080 (.001)	[.243]			
F = 3	F = 4		.085 (.010)	[.016]			
F = 4	F = 3		-.053 (.010)	[.016]			
F = 4	F = 4		.111 (.001)	[.301]			
F = 4	F = 5		-.019 (.008)	[.016]			
F = 5	F = 4		.090 (.008)	[.016]			
F = 5	F = 5		-.041 (.000)	[.391]			
4(0, 4)	3(0, 3)		254685.247 (.142)	[3.996]	21.281	12.786	
F = 3	F = 2		.011 (.001)	[.238]			
F = 3	F = 3		.527 (.025)	[.021]			
F = 4	F = 3		-.049 (.000)	[.313]			
F = 4	F = 4		-.432 (.019)	[.021]			
F = 5	F = 4		.027 (.000)	[.407]			
4(1, 4)	3(1, 3)		245125.974 (.160)	[3.749]	25.929	17.752	
F = 3	F = 2		.057 (.001)	[.238]			
F = 3	F = 3		1.656 (.024)	[.021]			
F = 4	F = 3		-.034 (.001)	[.313]			
F = 4	F = 4		-1.303 (.019)	[.021]			
F = 5	F = 4		.041 (.001)	[.407]			
4(1, 3)	3(1, 2)		266270.139 (.160)	[3.749]	27.693	18.811	
F = 3	F = 2		.076 (.001)	[.238]			
F = 3	F = 3		-1.002 (.022)	[.021]			
F = 4	F = 3		-.035 (.001)	[.313]			
F = 4	F = 4		.764 (.017)	[.021]			
F = 5	F = 4		-.006 (.001)	[.407]			
4(2, 3)	3(2, 2)		255840.431 (.226)	[3.000]	43.247	34.713	
F = 3	F = 2		.068 (.004)	[.238]			

TABLE 2. The microwave spectrum of methylenimine—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 = 3	– F = 3		.068 (.004)	[.021]			
F = 4	– F = 3		–.096 (.006)	[.313]			
F = 4	– F = 4		–.096 (.006)	[.021]			
F = 5	– F = 4		.035 (.002)	[.407]			
4(2, 2)	– 3(2, 1)		257112.755 (.225)	[3.000]	43.311	34.735	
F = 3	– F = 2		.039 (.004)	[.238]			
F = 3	– F = 3		–.073 (.004)	[.021]			
F = 4	– F = 3		–.046 (.006)	[.313]			
F = 4	– F = 4		.036 (.006)	[.021]			
F = 5	– F = 4		.015 (.002)	[.407]			
4(3, 2)	– 3(3, 1)		256165.440 (.339)	[1.750]	70.634	62.089	
F = 3	– F = 2		.161 (.011)	[.238]			
F = 3	– F = 3		–.358 (.021)	[.021]			
F = 4	– F = 3		–.191 (.013)	[.313]			
F = 4	– F = 4		.194 (.011)	[.021]			
F = 5	– F = 4		.061 (.004)	[.407]			
4(3, 1)	– 3(3, 0)		256176.986 (.339)	[1.750]	70.634	62.089	
F = 3	– F = 2		.161 (.011)	[.238]			
F = 3	– F = 3		–.360 (.021)	[.021]			
F = 4	– F = 3		–.190 (.013)	[.313]			
F = 4	– F = 4		.195 (.011)	[.021]			
F = 5	– F = 4		.060 (.004)	[.407]			
4(1, 3)	– 4(0, 4)		192212.448 (.112)	[4.172]	27.693	21.281	
F = 3	– F = 3		–.643 (.006)	[.243]			
F = 3	– F = 4		–.067 (.023)	[.016]			
F = 4	– F = 3		.324 (.023)	[.016]			
F = 4	– F = 4		.901 (.009)	[.301]			
F = 4	– F = 5		.442 (.018)	[.016]			
F = 5	– F = 4		.131 (.019)	[.016]			
F = 5	– F = 5		–.328 (.003)	[.391]			
4(0, 4)	– 3(1, 3)		105794.118 (.047)	[1.682]	21.281	17.752	
F = 3	– F = 2		–.521 (.005)	[.238]			
F = 3	– F = 3		1.192 (.023)	[.021]			
F = 4	– F = 3		.616 (.007)	[.313]			
F = 4	– F = 4		–.654 (.019)	[.021]			
F = 5	– F = 4		–.195 (.002)	[.407]			
3(2, 1)	– 4(1, 4)		263986.147 (.089)	[.346]	34.735	25.929	
F = 2	– F = 3		–.754 (.011)	[.238]			
F = 3	– F = 3		–.642 (.010)	[.021]			
F = 3	– F = 4		1.048 (.015)	[.313]			
F = 4	– F = 4		.965 (.015)	[.021]			
F = 4	– F = 5		–.379 (.006)	[.407]			
3(2, 2)	– 4(1, 3)		210467.551 (.075)	[.408]	34.713	27.693	
F = 2	– F = 3		.403 (.010)	[.238]			
F = 3	– F = 3		.403 (.010)	[.021]			
F = 3	– F = 4		–.564 (.013)	[.313]			
F = 4	– F = 4		–.564 (.013)	[.021]			
F = 4	– F = 5		.205 (.005)	[.407]			
5(1, 4)	– 5(1, 5)		79281.269 (.028)	[.368]	38.786	36.142	
F = 4	– F = 4	79280.130(0.15)	–1.032 (.010)	[.262]			72B
F = 4	– F = 5		.653 (.022)	[.011]			
F = 5	– F = 4		–.137 (.021)	[.011]			
F = 5	– F = 5	79282.840(0.11)	1.548 (.015)	[.311]			72B
F = 5	– F = 6		.148 (.018)	[.011]			
F = 6	– F = 5		.805 (.019)	[.011]			
F = 6	– F = 6	79280.720(0.13)	–.596 (.006)	[.383]			72B
5(2, 3)	– 5(2, 4)		4441.109 (.005)	[1.457]	54.057	53.909	
F = 4	– F = 4		–.115 (.001)	[.262]			
F = 4	– F = 5		.135 (.014)	[.011]			
F = 5	– F = 4		–.078 (.014)	[.011]			
F = 5	– F = 5		.172 (.002)	[.311]			
F = 5	– F = 6		–.035 (.012)	[.011]			
F = 6	– F = 5		.141 (.012)	[.011]			
F = 6	– F = 6		–.066 (.001)	[.383]			
5(1, 4)	– 5(0, 5)		207380.300 (.141)	[4.879]	38.786	31.869	
F = 4	– F = 4		–.623 (.006)	[.262]			
F = 4	– F = 5		.039 (.023)	[.011]			
F = 5	– F = 4		.272 (.022)	[.011]			
F = 5	– F = 5		.934 (.009)	[.311]			
F = 5	– F = 6		.384 (.019)	[.011]			
F = 6	– F = 5		.190 (.019)	[.011]			
F = 6	– F = 6		–.359 (.003)	[.383]			
5(0, 5)	– 4(1, 4)		178073.361 (.085)	[2.336]	31.869	25.929	
F = 4	– F = 3		–.440 (.004)	[.259]			
F = 4	– F = 4		1.251 (.024)	[.013]			
F = 5	– F = 4		.589 (.006)	[.320]			
F = 5	– F = 5		–.755 (.020)	[.013]			
F = 6	– F = 5		–.206 (.002)	[.394]			
4(2, 2)	– 5(1, 5)		214926.509 (.065)	[.522]	43.311	36.142	

TABLE 2. The microwave spectrum of methylenimine—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 = 3	F = 4		-.686 (.008)	[.259]			
F = 4	F = 4		-.659 (.015)	[.013]			
F = 4	F = 5		1.027 (.012)	[.320]			
F = 5	F = 5		1.006 (.017)	[.013]			
F = 5	F = 6		-.395 (.005)	[.394]			
4(2, 3)	5(1, 4)		133734.913 (.049)	[.671]	43.247	38.786	
F = 3	F = 4		.426 (.006)	[.259]			
F = 4	F = 4		.262 (.015)	[.013]			
F = 4	F = 5		-.633 (.009)	[.320]			
F = 5	F = 5		-.502 (.016)	[.013]			
F = 5	F = 6		.241 (.004)	[.394]			
6(1, 5)	6(1, 6)		110897.780 (.031)	[.311]	52.085	48.386	
F = 5	F = 5	110896.940(0.25)	-.983 (.009)	[.274]			72A
F = 6	F = 6	110899.280(0.25)	1.545 (.015)	[.318]			72A
F = 7	F = 7	110896.940(0.25)	-.618 (.006)	[.377]			72A
6(2, 4)	6(2, 5)		8827.419 (.008)	[1.223]	66.989	66.695	
F = 5	F = 5		-.155 (.001)	[.274]			
F = 6	F = 6		.243 (.002)	[.318]			
F = 7	F = 7		-.097 (.001)	[.377]			
6(3, 3)	6(3, 4)		161.330 (.001)	[2.781]	94.149	94.143	
F = 5	F = 5		-.004 (.000)	[.274]			
F = 6	F = 6		.007 (.000)	[.318]			
F = 7	F = 7		-.003 (.000)	[.377]			
6(1, 5)	6(0, 6)		226548.809 (.182)	[5.461]	52.085	44.528	
F = 5	F = 5		-.622 (.006)	[.274]			
F = 6	F = 6		.978 (.009)	[.318]			
F = 7	F = 7		-.391 (.004)	[.377]			
6(0, 6)	5(1, 5)		251421.379 (.139)	[3.053]	44.528	36.142	
F = 5	F = 4		-.377 (.004)	[.273]			
F = 6	F = 5		.544 (.005)	[.324]			
F = 7	F = 6		-.202 (.002)	[.385]			
5(2, 3)	6(1, 6)		170015.947 (.046)	[.672]	54.057	48.386	
F = 4	F = 5		-.673 (.007)	[.273]			
F = 5	F = 6		1.057 (.011)	[.324]			
F = 6	F = 7		-.422 (.004)	[.385]			
5(2, 4)	6(1, 5)		54677.058 (.030)	[.963]	53.909	52.085	
F = 4	F = 5	54677.350(0.07)	.425 (.005)	[.273]			72B
F = 5	F = 6	54676.380(0.08)	-.660 (.008)	[.324]			72B
F = 6	F = 7	54677.350(0.07)	.262 (.003)	[.385]			72B
7(1, 6)	7(1, 7)		147660.639 (.045)	[.271]	67.581	62.656	
F = 6	F = 6		-.947 (.009)	[.283]			
F = 7	F = 7		1.539 (.015)	[.322]			
F = 8	F = 8		-.634 (.006)	[.372]			
7(2, 5)	7(2, 6)		15738.411 (.013)	[1.049]	82.125	81.600	
F = 6	F = 6		-.198 (.002)	[.283]			
F = 7	F = 7		.322 (.003)	[.322]			
F = 8	F = 8		-.133 (.001)	[.372]			
7(3, 4)	7(3, 5)		402.532 (.002)	[2.403]	109.125	109.112	
F = 6	F = 6		-.008 (.000)	[.283]			
F = 7	F = 7		.013 (.000)	[.322]			
F = 8	F = 8		-.005 (.000)	[.372]			
7(1, 6)	7(0, 7)		250161.865 (.239)	[5.906]	67.581	59.237	
F = 6	F = 6		-.633 (.006)	[.283]			
F = 7	F = 7		1.029 (.010)	[.322]			
F = 8	F = 8		-.424 (.004)	[.372]			
6(2, 4)	7(1, 7)		129904.557 (.034)	[.786]	66.989	62.656	
F = 5	F = 6		-.686 (.007)	[.282]			
F = 6	F = 7		1.113 (.011)	[.327]			
F = 7	F = 8		-.458 (.005)	[.378]			
7(1, 6)	6(2, 5)		26583.501 (.027)	[1.284]	67.581	66.695	
F = 6	F = 5		-.415 (.004)	[.282]			
F = 7	F = 6		.669 (.007)	[.327]			
F = 8	F = 7		-.273 (.003)	[.378]			
8(1, 7)	8(1, 8)		189460.889 (.082)	[.241]	85.266	78.946	
F = 7	F = 7		-.918 (.009)	[.290]			
F = 8	F = 8		1.530 (.014)	[.324]			
F = 9	F = 9		-.644 (.006)	[.368]			
8(2, 6)	8(2, 7)		25873.423 (.017)	[.913]	99.483	98.620	
F = 7	F = 7		-.244 (.002)	[.290]			
F = 8	F = 8		.407 (.004)	[.324]			
F = 9	F = 9		-.171 (.002)	[.368]			
8(3, 5)	8(3, 6)		883.028 (.003)	[2.114]	126.254	126.225	
F = 7	F = 7		-.013 (.000)	[.290]			
F = 8	F = 8		.021 (.000)	[.324]			
F = 9	F = 9		-.009 (.000)	[.368]			
8(1, 7)	8(0, 8)		278642.705 (.312)	[6.211]	85.266	75.971	
F = 7	F = 7		-.649 (.006)	[.290]			
F = 8	F = 8		1.081 (.010)	[.324]			
F = 9	F = 9		-.455 (.004)	[.368]			

TABLE 2. The microwave spectrum of methylenimine—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	
7(2, 5)	– 8(1, 8)		95306.850 (.031)	[.859]	82.125	78.946	
F = 6	– F = 7		–.713 (.007)	[.289]			
F = 7	– F = 8		1.185 (.011)	[.328]			
F = 8	– F = 9		–.498 (.005)	[.373]			
8(1, 7)	– 7(2, 6)		109892.449 (.060)	[1.638]	85.266	81.600	
F = 7	– F = 6	109892.050(0.18)	–.403 (.004)	[.289]			72B
F = 8	– F = 7	109892.990(0.27)	.667 (.007)	[.328]			72B
F = 9	– F = 8	109892.050(0.18)	–.279 (.003)	[.373]			72B
7(3, 5)	– 8(2, 6)		288664.106 (.122)	[.941]	109.112	99.483	
F = 6	– F = 7		.140 (.003)	[.289]			
F = 7	– F = 8		–.232 (.005)	[.328]			
F = 8	– F = 9		.097 (.002)	[.373]			
9(1, 8)	– 9(1, 9)		236138.515 (.146)	[.217]	105.126	97.249	
F = 8	– F = 8		–.893 (.008)	[.295]			
F = 9	– F = 9		1.518 (.014)	[.326]			
F = 10	– F = 10		–.650 (.006)	[.365]			
9(2, 7)	– 9(2, 8)		39910.123 (.020)	[.803]	119.079	117.748	
F = 8	– F = 8		–.290 (.003)	[.295]			
F = 9	– F = 9		.493 (.005)	[.326]			
F = 10	– F = 10		–.211 (.002)	[.365]			
9(3, 6)	– 9(3, 7)		1758.919 (.005)	[1.884]	145.543	145.484	
F = 8	– F = 8		–.020 (.000)	[.295]			
F = 9	– F = 9		.034 (.000)	[.326]			
F = 10	– F = 10		–.015 (.000)	[.365]			
8(2, 6)	– 9(1, 9)		66955.091 (.033)	[.889]	99.483	97.249	
F = 7	– F = 8	66954.324(0.068)	–.747 (.007)	[.294]			72A
F = 8	– F = 9	66956.364(0.051)	1.267 (.012)	[.329]			72A
F = 9	– F = 10	66954.579(0.068)	–.542 (.005)	[.368]			72A
9(1, 8)	– 8(2, 7)		195056.847 (.124)	[2.029]	105.126	98.620	
F = 8	– F = 7		–.390 (.004)	[.294]			
F = 9	– F = 8		.657 (.007)	[.329]			
F = 10	– F = 9		–.280 (.003)	[.368]			
8(3, 5)	– 9(2, 8)		255016.038 (.086)	[1.125]	126.254	117.748	
F = 7	– F = 8		–.121 (.002)	[.294]			
F = 8	– F = 9		.207 (.004)	[.329]			
F = 9	– F = 10		–.089 (.002)	[.368]			
8(3, 6)	– 9(2, 7)		214222.886 (.078)	[1.168]	126.225	119.079	
F = 7	– F = 8		.182 (.003)	[.294]			
F = 8	– F = 9		–.308 (.005)	[.329]			
F = 9	– F = 10		.131 (.002)	[.368]			
10(1, 9)	– 10(1,10)		287470.679 (.242)	[.199]	127.149	117.560	
F = 9	– F = 9		–.869 (.008)	[.299]			
F = 10	– F = 10		1.500 (.014)	[.327]			
F = 11	– F = 11		–.652 (.006)	[.362]			
10(2, 8)	– 10(2, 9)		58451.106 (.021)	[.712]	140.928	138.978	
F = 9	– F = 9	58450.784(0.064)	–.335 (.003)	[.299]			72B
F = 10	– F = 10	58451.648(0.064)	.579 (.005)	[.327]			72B
F = 11	– F = 11	58450.784(0.064)	–.252 (.002)	[.362]			72B
10(3, 7)	– 10(3, 8)		3248.527 (.009)	[1.697]	166.999	166.891	
F = 9	– F = 9		–.030 (.000)	[.299]			
F = 10	– F = 10		.051 (.000)	[.327]			
F = 11	– F = 11		–.022 (.000)	[.362]			
9(2, 7)	– 10(1,10)		45542.839 (.036)	[.880]	119.079	117.560	
F = 8	– F = 9		–.785 (.007)	[.298]			
F = 9	– F = 10		1.352 (.013)	[.330]			
F = 10	– F = 11		–.586 (.006)	[.365]			
10(1, 9)	– 9(2, 8)		281837.963 (.225)	[2.464]	127.149	117.748	
F = 9	– F = 8		–.374 (.004)	[.298]			
F = 10	– F = 9		.642 (.006)	[.330]			
F = 11	– F = 10		–.277 (.003)	[.365]			
9(3, 6)	– 10(2, 9)		196818.221 (.051)	[1.321]	145.543	138.978	
F = 8	– F = 9		–.136 (.002)	[.298]			
F = 9	– F = 10		.237 (.003)	[.330]			
F = 10	– F = 11		–.103 (.002)	[.365]			
9(3, 7)	– 10(2, 8)		136608.196 (.044)	[1.400]	145.484	140.928	
F = 8	– F = 9		.219 (.003)	[.298]			
F = 9	– F = 10		–.377 (.005)	[.330]			
F = 10	– F = 11		.163 (.002)	[.365]			
11(2, 9)	– 11(2,10)		81980.083 (.026)	[.635]	165.037	162.302	
F = 10	– F = 10	81979.805(0.063)	–.378 (.004)	[.302]			72B
F = 11	– F = 11	81980.750(0.11)	.661 (.006)	[.328]			72B
F = 12	– F = 12	81979.805(0.063)	–.291 (.003)	[.360]			72B
11(3, 8)	– 11(3, 9)		5643.062 (.013)	[1.540]	190.633	190.445	
F = 10	– F = 10		–.042 (.000)	[.302]			
F = 11	– F = 11		.074 (.001)	[.328]			
F = 12	– F = 12		–.033 (.000)	[.360]			
10(2, 8)	– 11(1,11)		31667.462 (.039)	[.840]	140.928	139.871	
F = 9	– F = 10		–.823 (.008)	[.302]			
F = 10	– F = 11		1.437 (.014)	[.331]			

TABLE 2. The microwave spectrum of methylenimine—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 = 11	F = 12		-.631 (.006)	[.362]			
10(3, 7)	11(2,10)		140810.332 (.032)	[1.500]	166.999	162.302	
F = 9	F = 10		-.157 (.002)	[.302]			
F = 10	F = 11		.275 (.003)	[.331]			
F = 11	F = 12		-.121 (.001)	[.362]			
10(3, 8)	11(2, 9)		55581.721 (.027)	[1.638]	166.891	165.037	
F = 9	F = 10	55581.944(0.042)	.250 (.003)	[.302]			72B
F = 10	F = 11	55581.300(0.042)	-.437 (.005)	[.331]			72B
F = 11	F = 12	55581.944(0.042)	.192 (.002)	[.362]			72B
12(2,10)	12(2,11)		110836.614 (.051)	[.570]	191.411	187.714	
F = 11	F = 11	110836.280(0.36)	-.416 (.004)	[.305]			72A
F = 12	F = 12	110837.180(0.36)	.736 (.007)	[.329]			72A
F = 13	F = 13	110836.280(0.36)	-.327 (.003)	[.358]			72A
11(2, 9)	12(1,12)		25783.058 (.041)	[.777]	165.037	164.177	
F = 10	F = 11		-.859 (.008)	[.304]			
F = 11	F = 12		1.517 (.014)	[.331]			
F = 12	F = 13		-.673 (.006)	[.360]			
11(3, 8)	12(2,11)		87527.451 (.032)	[1.658]	190.633	187.714	
F = 10	F = 11		-.182 (.002)	[.304]			
F = 11	F = 12		.323 (.003)	[.331]			
F = 12	F = 13		-.144 (.002)	[.360]			
12(2,10)	11(3, 9)		28952.225 (.037)	[1.885]	191.411	190.445	
F = 11	F = 10		-.276 (.003)	[.304]			
F = 12	F = 11		.487 (.005)	[.331]			
F = 13	F = 12		-.216 (.002)	[.360]			
12(2,10)	13(1,13)		28173.026 (.040)	[.701]	191.411	190.471	
F = 11	F = 12		-.892 (.008)	[.307]			
F = 12	F = 13		1.589 (.015)	[.331]			
F = 13	F = 14		-.711 (.007)	[.358]			
14(2,12)	15(1,15)		58043.397 (.038)	[.542]	250.939	249.003	
F = 13	F = 14	58042.544(0.048)	-.941 (.009)	[.310]			72B
F = 14	F = 15	58045.088(0.048)	1.703 (.016)	[.332]			72B
F = 15	F = 16	58042.544(0.048)	-.773 (.007)	[.355]			72B
15(2,14)	14(3,11)		49550.029 (.037)	[1.946]	276.382	274.729	
F = 14	F = 13	49550.291(0.052)	.282 (.003)	[.310]			72B
F = 15	F = 14	49549.511(0.052)	-.510 (.005)	[.332]			72B
F = 16	F = 15	49550.291(0.052)	.232 (.002)	[.355]			72B
15(4,12)	16(3,13)		70160.901 (.037)	[2.356]	344.285	341.944	
F = 14	F = 15	70161.014(0.072)	.133 (.002)	[.312]			72A
F = 15	F = 16	70160.654(0.072)	-.243 (.003)	[.332]			72A
F = 16	F = 17	70161.014(0.072)	.111 (.001)	[.354]			72A
17(3,14)	17(3,15)		65200.464 (.029)	[.926]	378.946	376.772	
F = 16	F = 16	65200.315(0.068)	-.186 (.002)	[.313]			72A
F = 17	F = 17	65200.774(0.068)	.341 (.003)	[.331]			72A
F = 18	F = 18	65200.315(0.068)	-.156 (.001)	[.351]			72A
16(4,12)	17(3,15)	57293.416(0.042)	57293.420 (.031)	[2.486]	378.683	376.772	72B
F = 15	F = 16		.042 (.001)	[.313]			
F = 16	F = 17		.076 (.001)	[.332]			
F = 17	F = 18		-.035 (.001)	[.352]			
19(3,17)	18(4,14)	60491.120(0.050)	60491.119 (.039)	[2.799]	455.923	453.905	72A
F = 18	F = 17		.071 (.001)	[.315]			
F = 19	F = 18		-.132 (.002)	[.332]			
F = 20	F = 19		.061 (.001)	[.350]			
20(5,16)	21(4,17)	81105.600(0.10)	81105.595 (.076)	[3.104]	585.959	583.253	72B
F = 19	F = 20		.072 (.001)	[.317]			
F = 20	F = 21		-.134 (.002)	[.333]			
F = 21	F = 22		.062 (.001)	[.349]			
23(4,19)	22(5,18)	74714.520(0.10)	74714.570 (.053)	[3.508]	680.650	678.157	72B
F = 22	F = 21		-.103 (.001)	[.319]			
F = 23	F = 22		.192 (.002)	[.333]			
F = 24	F = 23		-.090 (.001)	[.348]			
24(4,20)	24(4,21)	62042.110(0.06)	62042.104 (.045)	[1.155]	732.744	730.674	72B
F = 23	F = 23		-.117 (.001)	[.319]			
F = 24	F = 24		.220 (.002)	[.332]			
F = 25	F = 25		-.103 (.001)	[.346]			
25(2.24)	24(3.21)		55155.251 (.045)	[.963]	703.884	702.044	
F = 24	F = 23	55155.882(0.056)	.667 (.006)	[.320]			72B
F = 25	F = 24	55153.992(0.056)	-1.255 (.012)	[.333]			72B
F = 26	F = 25	55155.882(0.056)	.592 (.006)	[.346]			72B
26(3,23)	27(2,26)		45007.484 (.144)	[.749]	814.749	813.248	
F = 25	F = 26	45006.800(0.18)	-.703 (.007)	[.321]			72B
F = 26	F = 27	45008.850(0.18)	1.330 (.013)	[.333]			72B
F = 27	F = 28	45006.800(0.18)	-.630 (.006)	[.345]			72B
28(5,23)	27(6,22)	63016.580(0.13)	63016.515 (.079)	[4.260]	1007.413	1005.311	72B
F = 27	F = 26		-.060 (.001)	[.321]			
F = 28	F = 27		.114 (.001)	[.333]			
29	F = 28		-.054 (.001)	[.345]			

TABLE 2. The microwave spectrum of methylenimine—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	
31(5,26)	– 31(5,27)	54249.330(0.08)	54249.332 (.063)	[1.388]	1201.985	1200.176	72B
F = 30	– F = 30		–.076 (.001)	[.322]			
F = 31	– F = 31		.146 (.001)	[.333]			
F = 32	– F = 32		–.069 (.001)	[.344]			
33(6,27)	– 32(7,26)	58676.330(0.06)	58676.333 (.048)	[5.020]	1398.238	1396.281	72B
F = 32	– F = 31		–.039 (.001)	[.323]			
F = 33	– F = 32		.075 (.001)	[.333]			
F = 34	– F = 33		–.036 (.000)	[.343]			

TABLE 3. Microwave transitions of methylenimine in order of frequency

Frequency	Transition	Estimated Uncertainty	Frequency	Transition	Estimated Uncertainty
127.709	2(2, 0) – 2(2, 1)	(.000)	109892.449	8(1, 7) – 7(2, 6)	(.060)
161.330	6(3, 3) – 6(3, 4)	(.001)	110836.613	12(2,10) – 12(2,11)	(.051)
402.532	7(3, 4) – 7(3, 5)	(.002)	110897.779	6(1, 5) – 6(1, 6)	(.031)
638.004	3(2, 1) – 3(2, 2)	(.001)	122692.376	2(1, 2) – 1(1, 1)	(.069)
883.028	8(3, 5) – 8(3, 6)	(.003)	127856.850	2(0, 2) – 1(0, 1)	(.062)
1758.919	9(3, 6) – 9(3, 7)	(.005)	129904.557	6(2, 4) – 7(1, 7)	(.034)
1910.327	4(2, 2) – 4(2, 3)	(.002)	133272.145	2(1, 1) – 1(1, 0)	(.068)
3240.527	10(3, 7) – 10(3, 8)	(.009)	133734.912	4(2, 3) – 5(1, 4)	(.049)
4441.109	5(2, 3) – 5(2, 4)	(.005)	136608.195	9(3, 7) – 10(2, 8)	(.044)
5290.124	1(1, 0) – 1(1, 1)	(.003)	140810.330	10(3, 7) – 11(2,10)	(.032)
5643.062	11(3, 8) – 11(3, 9)	(.013)	147660.637	7(1, 6) – 7(1, 7)	(.045)
8827.419	6(2, 4) – 6(2, 5)	(.008)	166851.816	1(1, 0) – 1(0, 1)	(.078)
15738.411	7(2, 5) – 7(2, 6)	(.013)	170015.945	5(2, 3) – 6(1, 6)	(.040)
15869.894	2(1, 1) – 2(1, 2)	(.010)	172267.113	2(1, 1) – 2(0, 2)	(.083)
25783.058	11(2, 9) – 12(1,12)	(.041)	178073.359	5(0, 5) – 4(1, 4)	(.085)
25873.423	8(2, 6) – 8(2, 7)	(.017)	180627.555	3(1, 2) – 3(0, 3)	(.093)
26583.501	7(1, 6) – 6(2, 5)	(.027)	183956.852	3(1, 3) – 2(1, 2)	(.110)
28173.026	12(2,10) – 13(1,13)	(.040)	189460.887	8(1, 7) – 8(1, 8)	(.082)
28952.225	12(2,10) – 11(3, 9)	(.037)	191462.941	3(0, 3) – 2(0, 2)	(.098)
31667.462	10(2, 8) – 11(1,11)	(.039)	191959.457	3(2, 2) – 2(2, 1)	(.155)
31736.427	3(1, 2) – 3(1, 3)	(.017)	192212.447	4(1, 3) – 4(0, 4)	(.112)
33704.842	1(1, 1) – 2(0, 2)	(.018)	192469.752	3(2, 1) – 2(2, 0)	(.155)
35065.723	3(0, 3) – 2(1, 2)	(.017)	195056.846	9(1, 8) – 8(2, 7)	(.124)
39910.123	9(2, 7) – 9(2, 8)	(.020)	196818.221	9(3, 6) – 10(2, 9)	(.051)
45007.483	26(3,23) – 27(2,26)	(.144)	199823.385	3(1, 2) – 2(1, 1)	(.108)
45542.839	9(2, 7) – 10(1,10)	(.036)	207380.299	5(1, 4) – 5(0, 5)	(.141)
49550.029	15(2,14) – 14(3,11)	(.037)	210467.551	3(2, 2) – 4(1, 3)	(.075)
52880.591	4(1, 3) – 4(1, 4)	(.024)	214222.885	8(3, 6) – 9(2, 7)	(.078)
54249.332	31(5,26) – 31(5,27)	(.063)	214926.508	4(2, 2) – 5(1, 5)	(.065)
54677.058	5(2, 4) – 6(1, 5)	(.030)	225554.691	1(1, 1) – 0(0, 0)	(.109)
55155.251	25(2,24) – 24(3,21)	(.045)	226548.809	6(1, 5) – 6(0, 6)	(.182)
55581.720	10(3, 8) – 11(2, 9)	(.027)	236138.514	9(1, 8) – 9(1, 9)	(.146)
57293.419	16(4,12) – 17(3,15)	(.031)	245125.973	4(1, 4) – 3(1, 3)	(.160)
58043.396	14(2,12) – 15(1,15)	(.038)	250161.865	7(1, 6) – 7(0, 7)	(.239)
58451.106	10(2, 8) – 10(2, 9)	(.021)	251421.379	6(0, 6) – 5(1, 5)	(.139)
58676.333	33(6,27) – 32(7,26)	(.048)	254685.246	4(0, 4) – 3(0, 3)	(.142)
60491.118	19(3,17) – 18(4,14)	(.039)	255016.037	8(3, 5) – 9(2, 8)	(.086)
62042.104	24(4,20) – 24(4,21)	(.045)	255840.430	4(2, 3) – 3(2, 2)	(.226)
63016.515	28(5,23) – 27(6,22)	(.079)	256165.439	4(3, 2) – 3(3, 1)	(.339)
63992.999	1(0, 1) – 0(0, 0)	(.031)	256176.984	4(3, 1) – 3(3, 0)	(.339)
65200.463	17(3,14) – 17(3,15)	(.029)	257112.754	4(2, 2) – 3(2, 1)	(.225)
66955.091	8(2, 6) – 9(1, 9)	(.033)	263986.145	3(2, 1) – 4(1, 4)	(.089)
70160.900	15(4,12) – 16(3,13)	(.037)	266270.137	4(1, 3) – 3(1, 2)	(.160)
74714.569	23(4,19) – 22(5,18)	(.053)	278642.703	8(1, 7) – 8(0, 8)	(.312)
79281.269	5(1, 4) – 5(1, 5)	(.028)	281837.961	10(1, 9) – 9(2, 8)	(.225)
81105.595	20(5,16) – 21(4,17)	(.076)	284254.066	2(1, 2) – 1(0, 1)	(.146)
81980.083	11(2, 9) – 11(2,10)	(.026)	284778.230	2(2, 1) – 3(1, 2)	(.106)
87527.450	11(3, 8) – 12(2,11)	(.032)	287470.676	10(1, 9) – 10(1,10)	(.242)
95306.850	7(2, 5) – 8(1, 8)	(.031)	288664.105	7(3, 5) – 8(2, 6)	(.122)
105794.117	4(0, 4) – 3(1, 3)	(.047)			

2.1. CH_2NH References

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