Microwave Spectra of Molecules of Astrophysical Interest

XIV. Vinyl Cyanide (Acrylonitrile)

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The available data of the microwave spectrum of vinyl cyanide are critically reviewed and tabulated. Molecular data such as rotational constants, centrifugal distortion constants, hyperfine coupling constants, dipole moments, and structural parameters are tabulated. Rotational transitions from 400 MHz to 200 GHz, which are likely to be of interest to radio astronomy, are calculated and tabulated along with their estimated 95% confidence limits.

Key Words: Interstellar molecules; microwave spectra; molecular parameters; radio astronomy; rotational transitions; vinyl cyanide.

Contents

1. Introduction

The present tables were prepared in response to the needs of the rapidly progressing field of molecular radio astronomy and are intended to update and revise the existing tabulated literature on molecules already identified in interstellar observations [1].[1] The spectral information tabulated includes predicted and observed transitions between 400 MHz and 200 GHz for vinyl cyanide, $^{12}CH_2{}^{12}CH^{12}C^{14}N$. To keep the tables at reasonable lengths the reported transitions have been limited further by several assumptions. With the exception of measured lines—which are all reported—the following additional limits have been adopted for the calculation of the transitions reported in table 5.

(1) The upper limit for the total rotational energy was fixed at 200 cm^{-1}.

(2) Transitions of the *a*-type $^{q}Q_{K_a}$-branch are calculated only for $K_a = 1$, 2 and 3.

(3) For *b*-type transitions only measured lines are entered. They are much weaker than the *a*-type transitions and are therefore unlikely to be observed in interstellar space.

It is felt that these limits are generous enough to allow for the presentation of all transitions which might be observed by existing telescopes, or by those likely to be developed in the next several years.

[1] Figures in brackets indicate literature references.

Spectral data on less abundant isotopic forms have also been presented when available. These include all the singly substituted ^{13}C and ^{15}N-containing species.

1.1. Molecular Parameter Tables

The rotational constants and centrifugal distortion constants presented in table 1 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. A few transitions were resolved by ^{14}N hyperfine structure. These splittings were analysed for the nuclear quadrupole coupling constants, which are also given in table 1, and then subtracted off the measured frequencies prior to the distortion analysis. Several measurements were excluded from the final distortion calculation since they exhibited excessively large deviations ($\geqq 130$ kHz) from the calculated frequencies. Details of the centrifugal distortion calculation and statistical analysis used in this review have been discussed by Gerry and Winnewisser [2], as well as by Helminger, Cook, and De Lucia [3]. This formulation is similar to those discussed by Kirchhoff [4] and by Steenbeckeliers [5]. As has been indicated earlier in this series, if the constants are to reproduce the observed spectra to within experimental error, then it is necessary to retain more significant figures in the spectral constants then indicated by the statistical error limits.

Table 2 contains the spectral constants evaluated for the less abundant isotopic species.

1.2. Microwave Spectral Tables

Table 3 contains P- and R-branch transitions of $^{12}CH_2{}^{12}CH^{12}C^{14}N$ in which ^{14}N quadrupole hyperfine structure was observed, along with the $3 \leftarrow 2$ transition. For each spectral line the first column contains the upper state and lower state quantum numbers in the form $J(K_aK_c)$ 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 ^{14}N nucleus, with $I_1 = 1$. The second column contains the experimentally observed frequencies with their estimated measurement uncertainties, and the final column the reference to the origin of the measurements.

Since table 5 contains only the unsplit asymmetric rotor frequencies (with the limitations discussed in the introduction), we have tabulated in table 4 for the a-type $K=1$ Q-branch transitions the predicted hyperfine splitting due to the ^{14}N-nucleus. With the exception of these transitions and those given in table 3 the hyperfine splittings of all other transitions have been omitted since the splitting of the stronger hyperfine components with relative intensity ≥ 0.03 is smaller than 200 kHz. In particular we have also omitted in table 3 the calculated hyperfine splittings of all a-type R-branch transitions (with $K_a > 2$), since to date none of these transitions has been observed in the interstellar medium. Most likely for vinyl cyanide they will therefore also not be observed by interstellar measurements.

Table 5 contains the observed and calculated frequencies of all the transitions of $^{12}CH_2{}^{12}CH^{12}C^{14}N$ in the designated limits. Also included are some transitions which lie above the arbitrary cut-off limit of 200 cm^{-1} but which were measured in the laboratory and included in the analysis. As with table 3 the first column contains the upper state and lower state quantum numbers in the form $J(K_aK_c)$. In all cases where the differences between the K-doubling transition frequencies are smaller than 1 kHz we have denoted the transitions by $J(K_a)$ only. The second column contains the observed unsplit line frequencies; the estimated experimental uncertainty is quoted in a footnote at the end of the table. The third column contains the calculated frequencies and estimated uncertainties in MHz. The calculated uncertainties represent approximately 95% confidence levels, calculated by doubling the standard deviations obtained in the least squares analysis.

The line strengths for the unsplit rotational transitions are given in column 4. These line strengths, denoted by ${}^xS(J'_{K_a'K_c'}; J''_{K_a''K_c''})$ are defined in this review as

$$ {}^xS(J'_{K_a'K_c'}; J''_{K_a''K_c''}) = \frac{(2J''+1)\,|\mu_{J'\leftarrow J''}|^2}{\mu_x^2}, $$

where the superscript x refers to one of the principal axis of the molecule ($x = a$, b, or c); $|\mu_{J'\leftarrow J''}|$ is the dipole moment matrix element connecting the upper, $J'_{K'_aK'_c}$, and lower $J''_{K''_aK''_c}$, 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 energy of each rotational level is included in table 5 under columns 5 and 6 in units of cm^{-1}. They were calculated from the rotational and centrifugal distortion constants used in the analysis. Measurements are referenced in the last column. The two asteriks mark transitions which have not been used in the analysis, either because the deviation between observed and calculated frequency was larger than three times the standard deviation of the fit, or because the lines showed unresolved (≤ 200 kHz) K-doubling.

The measured transition frequencies of the less abundant isotopic species are presented in table 6. They include only the species with single ^{13}C and ^{15}N substitutions, and include all the transitions presently available in the literature. The quantum numbers J, K_a, K_c are presented as in tables 3 and 4.

Finally, as a convenience to the user, the calculated unsplit transition frequencies of table 5 have been listed according to increasing frequency in table 7.

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.)

Δ, δ, τ — Quartic centrifugal distortion constants.

H, h	Sextic centrifugal distortion constants.
a, b, c	Principal axes corresponding to A, B, C.
μ, $\mu_x (X=a,b,c)$	Dipole moment and components of the dipole moment along the principal axis (Debye).
$\chi_{aa}, \ldots$	Elements of the quadrupole coupling tensor (MHz).
$r\ (X\text{–}Y)$	Distance between centers of mass of atom X and Y (Å).
$\sphericalangle(X, Y, Z)$	Angle between atoms X, Y, and Z (degrees).
I_a, I_b, I_c	Moments of inertia of the whole molecule with respect to the indicated principal axis.
F	Total angular momentum quantum number.
J	Total rotational angular momentum quantum number.
K_a	Projection of J on the symmetry axis in the limiting prolate symmetric top.
K_c	Projection of J on the symmetry axis in the limiting oblate symmetric top.
(. . .)	Parenthesis in the numerical listing contain measured or estimated uncertainties. These should be interpreted as: 1.532(30) = 1.532±0.030.

b. Conversion Factors

The following conversion factors have been used

$$A, B, C\ (\text{MHz}) = \frac{5.05357 \times 10^5}{I_{a,b,c}\ (\text{amu Å}^2)}$$

$$1\ \text{cm}^{-1} = 29979.25\ \text{MHz}$$

1.4. References

[1] D. R. Johnson, F. J. Lovas, and W. H. Kirchhoff, J. Phys. Chem. Ref. Data **1**, 1011 (1972).
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[6] J. K. G. Watson, J. Chem. Phys. **46**, 1935 (1967).

2. Vinyl Cyanide Spectral Tables

TABLE 1. Molecular Parameters for Vinyl Cyanide $^{12}CH_2{}^{12}CH^{12}C$

Rotational Constants (MHz) *

$\mathcal{A}$	=	49 850.6972	(166)
$\mathcal{B}$	=	4 971.21314	(142)
$\mathcal{C}$	=	4 513.82840	(142)

Distortion Constants (MHz)

Δ_J	=	2.24319	(376)	x 10^{-3}
Δ_{JK}	=	-8.54398	(358)	x 10^{-2}
Δ_K	=	2.71723	(230)	
δ_J	=	4.56912	(646)	x 10^{-4}
δ_K	=	2.4530	(120)	x 10^{-2}
H_J	=	4.14	(3.62)	x 10^{-9}
H_{JK}	=	1.32	(3.18)	x 10^{-7}
H_{JK}	=	-8.67	(1.05)	x 10^{-6}
H_K	=	4.268	(748)	x 10^{-4}
h_J	=	3.08	(1.51)	x 10^{-9}
h_{JK}	=	-2.50	(6.00)	x 10^{-7}
h_K	=	6.30	(4.01)	x 10^{-5}

Dipole Moment (Debye) Ref. 54

μ_a	=	3.68	(7)
μ_b	=	1.25	(3)

Nitrogen Quadrupole Coupling Constants (MHz) Ref. 59A

χ_{aa}	=	-3.69 (5)
$\chi_{bb} - \chi_{cc}$	=	-0.53 (19)

Structure (Å) Ref. 59A

r_s (C ≡ N)	=	1.164
r_s (C - C)	=	1.426
r_s (C = C)	=	1.339
r_s (C - H_1)	=	1.086
∢ (C - C = C)	=	$122^\circ 37'$
∢ (H - C - C)	=	$121^\circ 44'$

Watson's Determinable Parameters of Vinylcyanide [see Ref. 6]

$\mathcal{A}$	=	49850.7017 (166)	MHz
$\mathcal{B}$	=	4971.08221 (144)	MHz
$\mathcal{C}$	=	4513.79742 (144)	MHz
τ_{aaaa}'	=	-10.5361 (92)	MHz
τ_{bbbb}'	=	-12.628 (16)	kHz
τ_{cccc}'	=	-5.317 (16)	kHz
τ_1	=	314.84 (15)	kHz
$\tau_2/(A+B+C)$	=	19.113 (19)	kHz
$\Delta\tau^{(1)}$	=	-81.4 (70)	Hz

(1) Planarity defect $\Delta\tau = \tau'_{cccc} - (\tau_2 - C\tau_1)/(A+B)$

*In I^r representation, A-reduction [6]

TABLE 2. Rotational Constants of Isotopically Substituted Vinyl Cyanide, (Ref. 59A)

	$^{13}CH_2{}^{12}CH^{12}C^{14}N$	$^{12}CH_2{}^{13}CH^{12}C^{14}N$	$^{12}CH_2{}^{12}CH^{13}C^{14}N$	$^{12}CH_2{}^{12}CH^{12}C^{15}N$
A (MHz) *	49180. **	48645. **	49781.**	49647.**
B (MHz) *	4837.539	4948.741	4948.434	4819.619
C (MHz) *	4398.194	4485.416	4494.619	4387.054
$\Delta = I_C - I_A - I_B$ (amu Å²)	0.1598**	0.1598**	0.1598**	0.1598**

* Effective ground state rotational constants obtained by fitting transitions to the rigid rotor Hamiltonian.

**The rotational constant A_0 was calculated assuming the inertial defect Δ had the value 0.1598 amu Å² as in $^{12}CH_2{}^{12}CH^{12}C^{14}N$.

TABLE 3. Frequencies (in MHz) of Transitions of $^{12}CH_2{}^{12}CH^{12}C^{14}N$ with Resolved ^{14}N Quadrupole Hyperfine Structure

(1) Transition						(2) Observed Frequency (Est. Uncertainty)	(3) Calculated Frequency (Uncertainty)$^+$	(4) Rel. Int.	(5) Reference
J'	K_a'	K_c'	J"	K_a"	K_c"				
1	0	1	0	0	0		9 485.033 (3)		73A
	F'=	2		F"=	1	9 485.29 (0.1)	9 485.218 (4)	0.556	
		1			1	9 484.19 (0.1)	9 484.110 (12)	0.333	
		0			1	9 486.89 (0.1)	9 486.879 (26)	0.111	
2	0	2	1	0	1		18 966.535 (5)		59A
	F'=	3		F"=	2	18 966.61 (*)	18 966.614 (5)	0.467	
		2			2	18 965.48 (*)	18 965.427 (17)	0.083	
		2			1		18 966.534 (5)	0.250	
		1			1	18 968.41 (*)	18 968.382 (26)	0.083	
		1			0	18 965.48 (*)	18 965.612 (13)	0.111	
2	1	1	1	1	0		19 427.625 (6)		59A
	F'=	3		F"=	2	19 427.80 (*)	19 427.844 (6)	0.467	
		2			2		19 425.179 (28)	0.083	
		2			1	19 426.67 (*)	19 426.702 (13)	0.250	
		1			1		19 427.493 (48)	0.083	
		1			0	19 429.06 (*)	19 429.076 (34)	0.111	
2	1	2	1	1	1		18 513.081 (6)		59A
	F'=	3		F"=	2	18 513.31 (*)	18 513.311 (7)	0.467	
		2			2	18 512.68 (*)	18 512.633 (31)	0.083	
		2			1	18 512.14 (*)	18 512.158 (13)	0.250	
		1			1		18 513.213 (48)	0.083	
		1			0	18 514.43 (*)	18 514.400 (27)	0.111	
3	0	3	2	0	2		28 440.981 (8)		
	F'=	4		F"=	3		28 441.025 (8)	0.429	
		3			3		28 439.692 (18)	0.037	
		3			2		28 440.980 (8)	0.296	
		2			2		28 442.645 (25)	0.037	
		2			1		28 440.797 (8)	0.200	

TABLE 3. Frequencies (in MHz) of Transitions of $^{12}CH_2{}^{12}CH^{12}C^{14}N$ with Resolved ^{14}N Quadrupole Hyperfine Structure—Continued

(1) Transition						(2) Observed Frequency (Est. Uncertainty)	(3) Calculated Frequency (Uncertainty)+	(4) Rel. Int.	(5) Reference
J'	K_a'	K_c'	J"	K_a"	K_c"				
3	1	2	2	1	1		29 139.097 (8)		
		F' = 4			F" = 3		29 139.193 (8)	0.429	
		3			3		29 138.357 (31)	0.037	
		3			3		29 138.866 (9)	0.296	
		2			2		29 139.994 (41)	0.037	
		0			1		29 139.203 (10)	0.200	
3	1	3	2	1	2		27 767.352 (8)		
		F'= 4			F"= 3		27 767.454 (8)	0.429	
		3			3		27 766.443 (37)	0.037	
		3			2		27 767.121 (9)	0.296	
		2			2		27 768.486 (51)	0.037	
		2			1		27 767.431 (9)	0.200	
3	2	1	2	2	0		28 470.834 (8)		
		F'= 4			F"= 3		28 471.097 (9)	0.429	
		3			3		28 471.100 (9)	0.037	
		3			2		28 469.912 (14)	0.296	
		2			2		28 469.909 (16)	0.037	
		2			1		28 471.757 (14)	0.200	
3	2	2	2	2	1		28 456.932 (8)		
		F'= 4			F"= 3		28 457.196 (9)	0.429	
		3			3		28 457.196 (9)	0.037	
		3			2		28 456.009 (14)	0.296	
		2			2		28 456.009 (14)	0.037	
		2			1		28 457.855 (14)	0.200	
1	1	1	2	0	2		25 910.454 (13)		59A
		F'= 2			F"= 3	25 910.08 (*)	25 910.111 (14)	0.467	
		2			2	25 911.28 (*)	25 911.299 (19)	0.083	
		1			2	25 911.78 (*)	25 911.774 (29)	0.250	
		1			1		25 909.926 (29)	0.083	
		0			1	25 908.70 (*)	25 908.738 (48)	0.111	
2	1	2	3	0	3		15 982.553 (12)		73A
		F'= 3			F"= 4	15 982.38 (0.1)	15 982.395 (13)	0.429	
		3			3		15 983.629 (22)	0.037	
		2			3	15 982.91 (0.1)	15 982.951 (25)	0.269	
		2			2		15 981.286 (36)	0.037	
		1			2	15 982.38 (0.1)	15 982.340 (25)	0.200	

* The quoted measurement accuracy is $\leq\pm0.15$ MHz

+ Calculated uncertainties are twice the predicted standard deviations

TABLE 4. Hyperfine Structure of the K_a = 1 a-type Q branch (in MHz)

J'	K_a'	K_c'	J"	K_a"	K_c"	Calculated Frequency (uncertainty)*	Rel. Int.
1	1	0	1	1	1	457.283 (1)	
	F'=	2		F"=	2	457.257 (10)	0.417
		2			1	456.782 (18)	0.139
		1			2	457.889 (22)	0.139
		1			1	457.415 (48)	0.083
		1			0	458.602 (26)	0.111
		0			1	455.832 (34)	0.111
2	1	1	2	1	2	1 371.828 (2)	
	F'=	3		F"=	3	1 371.790 (14)	0.415
		3			2	1 372.468 (22)	0.052
		2			3	1 371.281 (16)	0.052
		2			2	1 371.960 (48)	0.231
		2			1	1 370.905 (12)	0.050
		1			2	1 372.751 (12)	0.050
		1			1	1 371.696 (48)	0.150
3	1	2	3	1	3	2 743.573 (5)	
	F'=	4		F"=	4	2 743.529 (17)	0.402
		3			3	2 743.705 (48)	0.280
		2			2	2 743.468 (38)	0.212
4	1	3	4	1	4	4 572.388 (7)	
	F'=	5		F"=	5	4 572.340 (19)	0.391
		4			4	4 572.520 (48)	0.301
		3			3	4 572.294 (35)	0.243

* Calculated uncertainties are twice the predicted standard deviations

TABLE 5. The microwave spectrum of vinyl cyanide

Transition Upper state – Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm^{-1} Upper state	Lower state	Remarks
a type *R* branch						
1(0, 1)– 0(0, 0)	9485.10	9485.033(.003)	1.000	.316	0.000	
2(0, 2)– 1(0, 1)	18966.54	18966.535(.005)	2.000	.949	.316	59A
2(1, 1)– 1(1, 0)	19427.59	19427.625(.005)	1.500	2.477	1.829	59A
2(1, 2)– 1(1, 1)	18513.09	18513.081(.006)	1.500	2.431	1.813	59A
3(0, 3)– 2(0, 2)	28440.99	28440.981(.008)	3.000	1.898	.949	59A
3(1, 2)– 2(1, 1)	29138.97	29139.097(.008)	2.667	3.449	2.477	59A **
3(1, 3)– 2(1, 2)	27767.32	27767.352(.008)	2.667	3.357	2.431	59A
3(2, 1)– 2(2, 0)	28470.60	28470.834(.008)	1.667	7.916	6.966	59A **
3(2, 2)– 2(2, 1)	28457.34	28456.932(.008)	1.667	7.916	6.966	59A **
4(0, 4)– 3(0, 3)		37904.851(.010)	4.000	3.162	1.898	
4(1, 3)– 3(1, 2)		38847.738(.010)	3.750	4.744	3.449	
4(1, 4)– 3(1, 3)	37018.87	37018.923(.011)	3.750	4.592	3.357	
4(2, 2)– 3(2, 1)		37974.369(.010)	3.000	9.183	7.916	
4(2, 3)– 3(2, 2)		37939.628(.010)	3.000	9.181	7.916	
4(3, 1)– 3(3, 0)		37952.733(.009)	1.750	16.699	15.433	
4(3, 2)– 3(3, 1)		37952.634(.009)	1.750	16.699	15.433	
5(0, 5)– 4(0, 4)		47354.650(.013)	4.999	4.742	3.162	
5(1, 4)– 4(1, 3)		48552.566(.012)	4.800	6.364	4.744	
5(1, 5)– 4(1, 4)		46266.935(.013)	4.800	6.135	4.592	
5(2, 3)– 4(2, 2)		47489.234(.012)	4.200	10.767	9.183	
5(2, 4)– 4(2, 3)		47419.799(.012)	4.200	10.763	9.181	
5(3, 2)– 4(3, 1)		47443.889(.011)	3.200	18.282	16.699	
5(3, 3)– 4(3, 2)		47443.542(.011)	3.200	18.282	16.699	

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition (Upper state – Lower state)	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm^{-1} Upper state	Lower state	Remarks
5(4, 2)– 4(4, 1)		47445.440(.010)	1.800	28.799	27.216	
5(4, 1)– 4(4, 0)		47445.440(.010)	1.800	28.799	27.216	
6(0, 6)– 5(0, 5)		56786.934(.014)	5.999	6.636	4.742	
6(1, 5)– 5(1, 4)		58252.568(.014)	5.833	8.307	6.364	
6(1, 6)– 5(1, 5)		55510.560(.014)	5.833	7.987	6.135	
6(2, 4)– 5(2, 3)		57018.189(.013)	5.333	12.669	10.767	
6(2, 5)– 5(2, 4)		56896.814(.013)	5.333	12.661	10.763	
6(3, 3)– 5(3, 2)		56937.116(.012)	4.500	20.181	18.282	
6(3, 4)– 5(3, 3)		56936.193(.012)	4.500	20.181	18.282	
6(4, 2)– 5(4, 1)		56936.494(.011)	3.333	30.698	28.799	
6(4, 3)– 5(4, 2)		56936.492(.011)	3.333	30.698	28.799	
6(5, 2)– 5(5, 1)		56942.531(.011)	1.833	44.207	42.308	
7(0, 7)– 6(0, 6)		66198.348(.016)	6.998	8.844	6.636	
7(1, 6)– 6(1, 5)		67946.690(.015)	6.857	10.573	8.307	
7(1, 7)– 6(1, 6)		64749.013(.016)	6.857	10.147	7.987	
7(2, 5)– 6(2, 4)		66563.902(.015)	6.428	14.889	12.669	
7(2, 6)– 6(2, 5)		66370.045(.015)	6.428	14.875	12.661	
7(3, 4)– 6(3, 3)		66432.921(.014)	5.714	22.397	20.181	
7(3, 5)– 6(3, 4)		66430.843(.014)	5.714	22.397	20.181	
7(4, 3)– 6(4, 2)		66428.621(.013)	4.714	32.914	30.698	
7(4, 4)– 6(4, 3)		66428.613(.013)	4.714	32.914	30.698	
7(5, 2)– 6(5, 1)		66434.343(.012)	3.429	46.423	44.207	
7(6, 1)– 6(6, 0)		66444.788(.013)	1.857	62.915	60.699	
8(0, 8)– 7(0, 7)		75585.695(.017)	7.997	11.365	8.844	
8(1, 7)– 7(1, 6)		77633.827(.016)	7.874	13.163	10.573	
8(1, 8)– 7(1, 7)		73981.556(.017)	7.875	12.614	10.147	
8(2, 6)– 7(2, 5)		76128.889(.015)	7.500	17.429	14.889	
8(2, 7)– 7(2, 6)		75838.866(.016)	7.500	17.404	14.875	
8(3, 5)– 7(3, 4)		75931.857(.014)	6.875	24.930	22.397	
8(3, 6)– 7(3, 5)		75927.705(.014)	6.875	24.929	22.397	
8(4, 4)– 7(4, 3)		75922.000(.013)	6.000	35.446	32.914	
8(4, 5)– 7(4, 4)		75921.978(.013)	6.000	35.446	32.914	
8(5)– 7(5)		75926.795(.013)	4.875	48.956	46.423	
8(6)– 7(6)		75937.822(.013)	3.500	65.448	62.915	
8(7)– 7(7)		75953.111(.016)	1.875	84.912	82.378	
9(0, 9)– 8(0, 8)		84946.004(.017)	8.996	14.199	11.365	
9(1, 8)– 8(1, 7)		87312.821(.017)	8.888	16.076	13.163	
9(1, 9)– 8(1, 8)		83207.509(.017)	8.888	15.390	12.614	
9(2, 7)– 8(2, 6)		85715.433(.016)	8.555	20.288	17.429	
9(2, 8)– 8(2, 7)		85302.654(.016)	8.555	20.250	17.404	
9(3, 6)– 8(3, 5)		85434.538(.015)	8.000	27.779	24.930	
9(3, 7)– 8(3, 6)		85426.932(.015)	8.000	27.779	24.929	
9(4, 5)– 8(4, 4)		85416.813(.014)	7.222	38.295	35.446	
9(4, 6)– 8(4, 5)		85416.762(.014)	7.222	38.295	35.446	
9(5)– 8(5)		85419.979(.013)	6.222	51.805	48.956	
9(6)– 8(6)		85431.223(.014)	5.000	68.298	65.448	
9(7)– 8(7)		85447.736(.016)	3.556	87.762	84.912	
9(8)– 8(8)		85468.411(.020)	1.889	110.184	107.333	
10(0, 10)– 9(0, 9)		94276.638(.018)	9.994	17.344	14.199	
10(1, 9)– 9(1, 8)	96982.49	96982.443(.017)	9.899	19.311	16.076	
10(1, 10)– 9(1, 9)		92426.253(.017)	9.899	18.473	15.390	
10(2, 8)– 9(2, 7)	95325.49	95325.484(.016)	9.600	23.467	20.288	
10(2, 9)– 9(2, 8)	94760.83	94760.788(.016)	9.599	23.411	20.250	
10(3, 7)– 9(3, 6)	94941.58	94941.643(.015)	9.100	30.946	27.779	
10(3, 8)– 9(3, 7)	94928.71	94928.619(.015)	9.100	30.945	27.779	
10(4, 6)– 9(4, 5)	94913.16	94913.246(.014)	8.400	41.461	38.295	
10(4, 7)– 9(4, 6)	94913.16	94913.134(.014)	8.400	41.461	38.295	
10(5)– 9(5)	94914.05	94913.985(.013)	7.500	54.971	51.805	
10(6)– 9(6)	94925.08	94925.036(.015)	6.400	71.464	68.298	
10(7)– 9(7)	94942.67	94942.531(.017)	5.100	90.929	87.762	
10(8)– 9(8)		94964.955(.021)	3.600	113.351	110.184	
10(9)– 9(9)		94991.592(.027)	1.900	138.715	135.547	
11(0, 11)–10(0, 10)	103575.58	103575.400(.018)	10.992	20.798	17.344	
11(1, 10)–10(1, 9)	106641.39	106641.394(.017)	10.907	22.868	19.311	

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state–Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm⁻¹ Upper state	Lower state	Remarks
11(1, 11)–10(1, 10)	101637.23	101637.236(.017)	10.908	21.863	18.473	
11(2, 9)–10(2, 8)	104960.66	104960.550(.016)	10.636	26.969	23.467	
11(2, 10)–10(2, 9)	104212.58	104212.654(.016)	10.636	26.887	23.411	
11(3, 8)–10(3, 7)	104453.85	104453.927(.015)	10.182	34.431	30.946	
11(3, 9)–10(3, 8)	104432.77	104432.793(.015)	10.182	34.429	30.945	
11(4, 7)–10(4, 6)	104411.49	104411.485(.013)	9.546	44.944	41.461	**
11(4, 8)–10(4, 7)	104411.49	104411.262(.013)	9.546	44.944	41.461	**
11(5, 6)–10(5, 5)	104408.93	104408.904(.013)	8.727	58.454	54.971	
11(5, 7)–10(5, 6)	104408.93	104408.903(.013)	8.727	58.454	54.971	
11(6)–10(6)	104419.33	104419.308(.015)	7.727	74.947	71.464	
11(7)–10(7)	104437.49	104437.516(.017)	6.546	94.413	90.929	
11(8)–10(8)	104461.50	104461.515(.021)	5.182	116.836	113.351	
11(9)–10(9)	104490.36	104490.361(.027)	3.636	142.201	138.715	
11(10)–10(10)	104523.87	104523.548(.035)	1.909	170.491	167.004	**
12(0, 12)–11(0, 11)		112840.648(.017)	11.990	24.562	20.798	
12(1, 11)–11(1, 10)		116288.292(.017)	11.914	26.747	22.868	
12(1, 12)–11(1, 11)		110839.981(.017)	11.915	25.560	21.863	
12(2, 10)–11(2, 9)		114621.577(.016)	11.666	30.792	26.969	
12(2, 11)–11(2, 10)		113657.642(.016)	11.666	30.678	26.887	
12(3, 9)–11(3, 8)		113972.228(.014)	11.250	38.232	34.431	
12(3, 10)–11(3, 9)		113939.410(.014)	11.250	38.230	34.429	
12(4, 8)–11(4, 7)		113911.724(.013)	10.667	48.744	44.944	
12(4, 9)–11(4, 8)		113911.307(.013)	10.667	48.744	44.944	
12(5, 7)–11(5, 6)		113904.825(.013)	9.917	62.253	58.454	
12(5, 8)–11(5, 7)		113904.823(.013)	9.917	62.253	58.454	
12(6)–11(6)		113914.082(.015)	9.000	78.747	74.947	
12(7)–11(7)		113932.707(.018)	7.917	98.213	94.413	
12(8)–11(8)		113958.092(.021)	6.667	120.637	116.836	
12(9)–11(9)		113989.016(.026)	5.250	146.003	142.201	
12(10)–11(10)		114024.832(.034)	3.667	174.294	170.491	
13(0, 13)–12(0, 12)		122071.413(.017)	12.987	28.634	24.562	
13(1, 12)–12(1, 11)		125921.667(.017)	12.920	30.947	26.747	
13(1, 13)–12(1, 12)		120034.083(.016)	12.921	29.564	25.560	
13(2, 11)–12(2, 10)		124308.835(.015)	12.692	34.938	30.792	
13(2, 12)–12(2, 11)		123095.151(.015)	12.691	34.784	30.678	
13(3, 10)–12(3, 9)		123497.472(.014)	12.308	42.352	38.232	
13(3, 11)–12(3, 10)		123448.353(.014)	12.308	42.347	38.230	
13(4, 9)–12(4, 8)		123414.165(.013)	11.769	52.860	47.744	
13(4, 10)–12(4, 9)		123413.425(.013)	11.769	52.860	48.744	
13(5, 8)–12(5, 7)		123401.840(.013)	11.077	66.369	62.253	
13(5, 9)–12(5, 8)		123401.834(.013)	11.077	66.369	62.253	
13(6)–12(6)		123409.404(.015)	10.231	82.864	78.747	
13(7)–12(7)		123428.124(.018)	9.231	102.330	98.213	
13(8)–12(8)		123454.687(.021)	8.077	124.755	120.637	
13(9)–12(9)		123487.549(.025)	6.769	150.122	146.003	
13(10)–12(10)		123525.891(.033)	5.308	178.415	174.294	
14(0, 14)–13(0, 13)	131267.422	131267.478(.017)	13.985	33.013	28.634	
14(1, 13)–13(1, 12)	135539.974	135539.954(.016)	13.925	35.468	30.947	
14(1, 14)–13(1, 13)	129219.213	129219.221(.016)	13.926	33.875	29.564	
14(2, 12)–13(2, 11)	134021.823	134021.830(.015)	13.713	39.409	34.938	
14(2, 13)–13(2, 12)	132524.583	132524.590(.015)	13.713	39.205	34.784	
14(3, 11)–13(3, 10)	133030.674	133030.680(.013)	13.357	46.789	42.352	
14(3, 12)–13(3, 11)	132959.401	132959.423(.013)	13.357	46.782	42.347	
14(4, 10)–13(4, 9)	132918.991	132919.017(.012)	12.857	57.294	52.860	
14(4, 11)–13(4, 10)	132917.752	132917.762(.012)	12.857	57.294	52.860	
14(5, 9)–13(5, 8)	132900.010	132900.038(.013)	12.214	70.803	66.369	
14(5, 10)–13(5, 9)	132900.010	132900.027(.013)	12.214	70.803	66.369	
14(6)–13(6)	132905.288	132905.317(.015)	11.429	87.297	82.864	
14(7)–13(7)	132923.739	132923.783(.018)	10.500	106.764	102.330	
14(8)–13(8)	132951.274	132951.302(.021)	9.429	129.190	124.755	
14(9)–13(9)	132985.953	132985.947(.024)	8.214	154.558	150.122	
14(10)–13(10)	133025.756	133026.706(.030)	6.857	182.852	178.415	
14(11)–13(11)	133073.083	133072.990(.043)	5.357	214.051	209.612	
15(0, 15)–14(0, 14)	140429.480	140429.438(.017)	14.982	37.697	33.013	

Table 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state–Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm^{-1} Upper state	Lower state	Remarks
15(1, 14)–14(1, 13)	145141.487	145141.495(.017)	14.929	40.309	35.468	
15(1, 15)–14(1, 14)	138395.160	138395.151(.016)	14.930	38.491	33.875	
15(2, 13)–14(2, 12)	143759.253	143759.247(.015)	14.733	44.204	39.409	
15(2, 14)–14(2, 13)	141945.385	141945.379(.015)	14.731	43.939	39.205	
15(3, 12)–14(3, 11)	142572.930	142572.970(.013)	14.400	51.545	46.789	
15(3, 13)–14(3, 12)	142472.400	142472.348(.013)	14.400	51.535	46.782	
15(4, 11)–14(4, 10)	142426.490	142426.506(.013)	13.933	62.045	57.294	
15(4, 12)–14(4, 11)	142424.445	142424.454(.013)	13.933	62.045	57.294	
15(5, 10)–14(5, 9)	142399.510	142399.510(.014)	13.333	75.552	70.803	
15(5, 11)–14(5, 10)	142399.510	142399.489(.014)	13.333	75.552	70.803	
15(6)–14(6)	142401.950	142401.867(.016)	12.600	92.047	87.297	
15(7)–14(7)	142419.675	142419.704(.019)	11.733	111.515	106.764	
15(8)–14(8)	142448.00	142447.936(.021)	10.733	133.941	129.190	
15(9)–14(9)	142484.17	142484.201(.022)	9.600	159.311	154.558	
15(10)–14(10)	142527.21	142527.259(.027)	8.333	187.606	182.852	
15(11)–14(11)	142576.31	142576.393(.040)	6.933	218.807	214.051	
16(0, 16)–15(0, 15)		149558.702(.017)	15.979	42.686	37.697	
16(1, 15)–15(1, 14)		154724.531(.017)	15.932	45.471	40.309	
16(1, 16)–15(1, 15)		147561.708(.017)	15.934	43.413	38.491	
16(2, 14)–15(2, 13)		153518.944(.016)	15.749	49.325	44.204	
16(2, 15)–15(2, 14)		151356.951(.015)	15.747	48.988	43.939	
16(3, 13)–15(3, 12)		152125.561(.014)	15.437	56.619	51.545	
16(3, 14)–15(3, 13)		151986.773(.014)	15.437	56.605	51.535	
16(4, 12)–15(4, 11)		151936.868(.014)	15.000	67.113	62.045	
16(4, 13)–15(4, 12)		151933.624(.014)	15.000	67.113	62.045	
16(5, 11)–15(5, 10)		151900.347(.015)	14.438	80.619	75.552	
16(5, 12)–15(5, 11)		151900.309(.015)	14.438	80.619	75.552	
16(6, 10)–15(6, 9)		151899.097(.018)	13.750	97.114	92.047	
16(6, 11)–15(6, 10)		151899.097(.018)	13.750	97.114	92.047	
16(7)–15(7)		151915.902(.021)	12.938	116.582	111.515	
16(8)–15(8)		151944.590(.022)	12.000	139.010	133.941	
16(9)–15(9)		151982.298(.022)	10.938	164.381	159.311	
16(10)–15(10)		152027.529(.024)	9.750	192.677	187.606	
17(0, 17)–16(0, 16)		158657.432(.018)	16.976	47.978	42.686	
17(1, 16)–16(1, 15)		164287.210(.019)	16.934	50.951	45.471	
17(1, 17)–16(1, 16)		156718.809(.018)	16.937	48.641	43.413	
17(2, 15)–16(2, 14)		163298.006(.018)	16.765	54.772	49.325	
17(2, 16)–16(2, 15)		160758.759(.017)	16.761	54.350	48.988	
17(3, 14)–16(3, 13)		161689.763(.016)	16.470	62.013	56.619	
17(3, 15)–16(3, 14)		161502.271(.016)	16.470	61.992	56.605	
17(4, 13)–16(4, 12)		161450.362(.016)	16.059	72.498	67.113	
17(4, 14)–16(4, 13)		161445.382(.016)	16.059	72.498	67.113	
17(5, 12)–16(5, 11)		161402.641(.018)	15.530	86.003	80.619	
17(5, 13)–16(5, 12)		161402.574(.018)	15.530	86.003	80.619	
17(6, 11)–16(6, 10)		161397.051(.021)	14.882	102.497	97.114	
17(6, 12)–16(6, 11)		161397.050(.021)	14.882	102.497	97.114	
17(7)–16(7)		161412.397(.024)	14.118	121.966	116.582	
17(8)–16(8)		161441.265(.025)	13.235	144.395	139.010	
17(9)–16(9)		161480.229(.025)	12.235	169.767	164.381	
17(10)–16(10)		161527.499(.025)	11.118	198.065	192.677	
18(0, 18)–17(0, 17)		167728.434(.020)	17.974	53.573	47.978	
18(1, 17)–17(1, 16)		173827.595(.021)	17.936	56.749	50.951	
18(1, 18)–17(1, 17)		165866.445(.020)	17.939	54.173	48.641	
18(2, 16)–17(2, 15)		173092.852(.020)	17.778	60.546	54.772	
18(2, 17)–17(2, 16)		170150.272(.019)	17.774	60.026	54.350	
18(3, 15)–17(3, 14)		171266.976(.018)	17.500	67.725	62.013	
18(3, 16)–17(3, 15)		171018.336(.018)	17.500	67.696	61.992	
18(4, 14)–17(4, 13)		170967.269(.019)	17.111	78.201	72.498	
18(4, 15)–17(4, 14)		170959.817(.019)	17.111	78.201	72.498	
18(5, 13)–17(5, 12)		170906.484(.021)	16.611	91.704	86.003	
18(5, 14)–17(5, 13)		170906.370(.021)	16.611	91.704	86.003	
18(6, 12)–17(6, 11)		170895.772(.025)	16.000	108.198	102.497	
18(6, 13)–17(6, 12)		170895.771(.025)	16.000	108.198	102.497	
18(7)–17(7)		170909.204(.028)	15.278	127.667	121.966	

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state–Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm⁻¹ Upper state	Lower state	Remarks
18(8)–17(8)		170937.960(.030)	14.445	150.097	144.395	
18(9)–17(9)		170977.981(.030)	13.500	175.470	169.767	
18(10)–17(10)		171027.147(.030)	12.445	203.770	198.065	
19(0, 19)–18(0, 18)		176774.996(.023)	18.971	59.469	53.573	
19(1, 18)–18(1, 17)	183343.63	183343.676(.024)	18.937	62.864	56.749	
19(1, 19)–18(1, 18)		175004.678(.022)	18.941	60.011	54.173	
19(2, 17)–18(2, 16)	182899.39	182899.394(.024)	18.790	66.647	60.546	
19(2, 18)–18(2, 17)		179530.985(.022)	18.785	66.014	60.026	
19(3, 16)–18(3, 15)	180858.66	180858.669(.021)	18.526	73.758	67.725	
19(3, 17)–18(3, 16)	180534.30	180534.396(.022)	18.526	73.718	67.696	
19(4, 15)–18(4, 14)	180487.99	180487.898(.022)	18.158	84.222	78.201	
19(4, 16)–18(4, 15)	180476.95	180476.998(.022)	18.158	84.221	78.201	
19(5, 14)–18(5, 13)	180411.85	180411.971(.025)	17.684	97.722	91.704	**
19(5, 15)–18(5, 14)	180411.85	180411.784(.025)	17.684	97.722	91.704	**
19(6, 13)–18(6, 12)	180395.36	180395.305(.030)	17.105	114.215	108.198	
19(6, 14)–18(6, 13)	180395.36	180395.303(.030)	17.105	114.215	108.198	**
19(7)–18(7)	180406.29	180406.340(.035)	16.421	133.685	127.667	
19(8)–18(8)	180434.80	180434.677(.038)	15.632	156.115	150.097	
19(9)–18(9)	180475.23	180475.543(.039)	14.737	181.490	175.470	**
19(10)–18(10)	180526.47	180526.455(.040)	13.737	209.792	203.770	
19(11)–18(11)	180585.88	180585.994(.045)	12.632	241.000	234.977	
19(12)–18(12)	180653.34	180653.285(.065)	11.421	275.095	269.069	
20(0, 20)–19(0, 19)		185800.697(.026)	19.969	65.667	59.469	
20(1, 19)–19(1, 18)		192833.396(.027)	19.937	69.297	62.864	
20(1, 20)–19(1, 19)		184133.640(.026)	19.943	66.153	60.011	
20(2, 18)–19(2, 17)		192713.222(.028)	19.802	73.075	66.647	
20(2, 19)–19(2, 18)		188900.417(.025)	19.795	72.316	66.014	
20(3, 17)–19(3, 16)		190466.359(.025)	19.549	80.112	73.758	
20(3, 18)–19(3, 17)		190049.815(.026)	19.549	80.058	73.718	
20(4, 16)–19(4, 15)		190012.590(.027)	19.200	90.560	84.222	
20(4, 17)–19(4, 16)		189996.968(.027)	19.200	90.558	84.221	
20(5, 15)–19(5, 14)		189919.198(.031)	18.750	104.057	97.722	
20(5, 16)–19(5, 15)		189918.900(.031)	18.750	104.057	97.722	
20(6, 14)–19(6, 13)		189895.692(.037)	18.200	120.549	114.215	
20(6, 15)–19(6, 14)		189895.689(.037)	18.200	120.549	114.215	
20(7)–19(7)		189903.823(.043)	17.550	140.019	133.685	
20(8)–19(8)		189931.414(.049)	16.800	162.451	156.115	
20(9)–19(9)		189972.905(.052)	15.950	187.827	181.490	
21(0, 21)–20(0, 20)		194809.207(.030)	20.966	72.165	65.667	
21(1, 20)–20(1, 19)		202294.681(.031)	20.937	76.045	69.297	
21(1, 21)–20(1, 20)		193253.522(.030)	20.945	72.599	66.153	
21(2, 19)–20(2, 18)		202529.800(.032)	20.812	79.831	73.075	
21(2, 20)–20(2, 19)		198258.117(.029)	20.803	78.929	72.316	
21(3, 18)–20(3, 17)		200091.580(.030)	20.571	86.786	80.112	
21(3, 19)–20(3, 18)		199563.899(.031)	20.571	86.714	80.058	
21(4, 17)–20(4, 16)		199541.725(.033)	20.238	97.216	90.560	
21(4, 18)–20(4, 17)		199519.744(.033)	20.238	97.214	90.558	
21(5, 16)–20(5, 15)		199428.263(.038)	19.810	110.709	104.057	
21(5, 17)–20(5, 16)		199427.798(.038)	19.810	110.709	104.057	
21(6, 15)–20(6, 14)		199396.977(.045)	19.286	127.201	120.549	
21(6, 16)–20(6, 15)		199396.972(.045)	19.286	127.201	120.549	
21(7)–20(7)		199401.668(.054)	18.667	146.671	140.019	
21(8)–20(8)		199428.172(.062)	17.953	169.103	162.451	
21(9)–20(9)		199470.053(.068)	17.143	194.481	187.827	
a type *Q* branch						
1(1, 0)– 1(1, 1)		457.283(.001)	1.500	1.829	1.813	
2(1, 1)– 2(1, 2)		1371.828(.002)	.833	2.477	2.431	
3(1, 2)– 3(1, 3)		2743.573(.005)	.583	3.449	3.357	
4(1, 3)– 4(1, 4)		4572.388(.007)	.450	4.744	4.592	
5(1, 4)– 5(1, 5)		6858.018(.011)	.367	6.364	6.135	
6(1, 6)– 6(1, 6)	9600.07	9600.026(.014)	.310	8.307	7.987	
7(1, 6)– 7(1, 7)	12797.71	12797.703(.017)	.268	10.573	10.147	
8(1, 7)– 8(1, 8)	16450.01	16449.974(.020)	.237	13.163	12.614	
9(1, 8)– 9(1, 9)	20555.32	20555.286(.022)	.212	16.076	15.390	73B

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state–Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm⁻¹ Upper state	Lower state	Remarks
10(1, 9)–10(1, 10)	25111.40	25111.476(.024)	.192	19.311	18.473	73B
11(1, 10)–11(1, 11)	30115.65	30115.634(.026)	.175	22.868	21.863	73B
12(1, 11)–12(1, 12)	35563.92	35563.945(.027)	.162	26.747	25.560	73B
13(1, 12)–13(1, 13)		41451.528(.028)	.150	30.947	29.564	
14(1, 13)–14(1, 14)		47772.261(.031)	.140	35.468	33.875	
15(1, 14)–15(1, 15)		54518.605(.034)	.132	40.309	38.491	
16(1, 15)–16(1, 16)		61681.428(.039)	.125	45.471	43.413	
17(1, 16)–17(1, 17)		69429.829(.046)	.119	50.951	48.641	
18(1, 17)–18(1, 18)		77210.979(.052)	.113	56.749	54.173	
19(1, 18)–19(1, 19)		85549.977(.058)	.108	62.864	60.011	
20(1, 19)–20(1, 20)		94249.732(.061)	.104	69.297	66.153	
21(1, 20)–21(1, 21)		103290.891(.060)	.101	76.045	72.599	
22(1, 21)–22(1, 22)		112651.805(.057)	.098	83.107	79.349	
23(1, 22)–23(1, 23)		122308.565(.055)	.095	90.483	86.403	
24(1, 23)–24(1, 24)		132235.114(.069)	.093	98.171	93.760	
25(1, 24)–25(1, 25)		142403.431(.112)	.091	106.170	101.420	
26(1, 25)–26(1, 26)		152783.822(.185)	.089	114.480	109.383	
27(1, 26)–27(1, 27)		163345.300(.290)	.088	123.098	117.649	
28(1, 27)–28(1, 28)		174056.053(.429)	.087	132.023	126.217	
29(1, 28)–29(1, 29)		184884.004(.609)	.086	141.255	135.087	
30(1, 29)–30(1, 30)		195797.420(.836)	.086	150.791	144.260	
7(2, 5)– 7(2, 6)		436.787(.003)	1.069	14.889	14.875	
8(2, 6)– 8(2, 7)		726.810(.005)	.941	17.429	17.404	
9(2, 7)– 9(2, 8)		1139.589(.007)	.840	20.288	20.250	
10(2, 8)–10(2, 9)		1704.284(.010)	.757	23.467	23.411	
11(2, 9)–11(2, 10)		2452.181(.013)	.689	26.969	26.887	
12(2, 10)–12(2, 11)		3416.115(.016)	.631	30.792	30.678	
13(2, 11)–13(2, 12)		4629.799(.019)	.580	34.938	34.784	
14(2, 12)–14(2, 13)		6127.040(.021)	.537	39.409	39.205	
15(2, 13)–15(2, 14)		7940.908(.024)	.498	44.204	43.939	
16(2, 14)–16(2, 15)	10102.90	10102.901(.025)	.464	49.325	48.988	
17(2, 15)–17(2, 16)	12642.12	12642.148(.025)	.433	54.772	54.350	
18(2, 16)–18(2, 17)	15584.71	15584.727(.024)	.405	60.546	60.026	
19(2, 17)–19(2, 18)	18953.19	18953.136(.023)	.379	66.647	66.014	
20(2, 18)–20(2, 19)		22765.942(.023)	.356	73.075	72.316	
21(2, 19)–21(2, 20)		27037.625(.025)	.335	79.831	78.929	
22(2, 20)–22(2, 21)		31778.598(.030)	.315	86.914	85.854	
23(2, 21)–23(2, 22)	36995.37	36995.369(.038)	.298	94.324	93.090	
24(2, 22)–24(2, 23)		42690.811(.048)	.282	102.061	100.637	
25(2, 23)–25(2, 24)		48864.479(.057)	.267	110.124	108.495	
26(2, 24)–26(2, 25)		55512.952(.065)	.253	118.514	116.662	
27(2, 25)–27(2, 26)		62630.153(.070)	.241	127.228	125.139	
28(2, 26)–28(2, 27)		70207.624(.073)	.230	136.267	133.925	
29(2, 27)–29(2, 28)		78234.756(.076)	.220	145.630	143.020	
30(2, 28)–30(2, 29)		86698.950(.091)	.211	155.315	152.423	
31(2, 29)–31(2, 30)		95585.727(.128)	.203	165.322	162.134	
32(2, 30)–32(2, 31)		104878.790(.195)	.195	175.650	172.152	
33(2, 31)–33(2, 32)		114560.051(.296)	.189	186.298	182.477	
34(2, 32)–34(2, 33)		124609.627(.435)	.183	197.264	193.108	
16(3, 13)–16(3, 14)		441.984(.008)	1.084	56.619	56.605	
17(3, 14)–17(3, 15)		629.477(.011)	1.020	62.013	61.992	
18(3, 15)–18(3, 16)		878.117(.013)	.962	67.725	67.696	
19(3, 16)–19(3, 17)		1202.390(.016)	.910	73.758	73.718	
20(3, 17)–20(3, 18)		1618.933(.019)	.863	80.112	80.058	
21(3, 18)–21(3, 19)		2146.615(.022)	.819	86.786	86.714	
22(3, 19)–22(3, 20)		2806.551(.025)	.779	93.782	93.688	
23(3, 20)–23(3, 21)		3622.068(.027)	.742	101.100	100.980	
24(3, 21)–24(3, 22)		4618.582(.029)	.707	108.742	108.588	
25(3, 22)–25(3, 23)		5823.401(.030)	.675	116.707	116.513	
26(3, 23)–26(3, 24)		7265.421(.030)	.644	124.997	124.755	
27(3, 24)–27(3, 25)	8974.73	8974.733(.030)	.615	133.613	133.313	
28(3, 25)–28(3, 26)	10982.13	10982.127(.030)	.588	142.554	142.188	
29(3, 26)–29(3, 27)	13318.53	13318.519(.030)	.562	151.823	151.379	

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state	Transition Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm⁻¹ Upper state	Energy levels in cm⁻¹ Lower state	Remarks
30(3, 27)	30(3, 28)	16014.31	16014.304(.032)	.537	161.420	160.885	
31(3, 28)	31(3, 29)		19098.682(.035)	.513	171.344	170.707	
32(3, 29)	32(3, 30)		22598.978(.038)	.490	181.598	180.844	
33(3, 30)	33(3, 31)		26540.007(.042)	.468	192.181	191.296	
35(3, 32)	35(3, 33)	35827.73	35827.716(.069)	.428	214.337	213.142	
39(4, 35)	39(4, 36)	8164.26	8164.252(.051)	.750	271.672	271.400	
40(4, 36)	40(4, 37)	9835.96	9835.980(.061)	.725	284.427	284.099	
b type							
1(1, 1)	2(0, 2)	25910.44	25910.454(.013)	.508	1.813	.949	59A
2(1, 2)	3(0, 3)	15982.54	15982.553(.012)	1.025	2.431	1.898	
6(0, 6)	5(1, 5)	15010.70	15010.671(.013)	2.677	6.636	6.135	
7(0, 7)	6(1, 6)	25698.45	25698.459(.014)	3.273	8.844	7.987	59A
8(0, 8)	7(1, 7)	36535.20	36535.141(.015)	3.896	11.365	10.147	
17(0, 17)	16(1, 16)	136855.637	136855.594(.026)	11.047	47.978	43.413	
23(1, 22)	23(0, 23)	132555.533	132555.555(.043)	11.091	90.483	86.061	
24(1, 23)	24(0, 24)	141277.442	141277.461(.058)	10.967	98.171	93.459	
12(1, 12)	11(0, 11)	142759.361	142759.353(.027)	7.372	25.560	20.798	
8(2, 7)	9(1, 8)	39836.25	39836.197(.027)	1.691	17.404	16.076	73B
9(2, 8)	10(1, 9)	28156.40	28156.408(.027)	1.988	20.250	19.311	73B
19(2, 9)	11(1, 10)	16275.80	16275.801(.027)	2.296	23.411	22.868	
13(1, 12)	12(2, 11)	8063.89	8063.862(.026)	2.958	30.947	30.678	
14(1, 13)	13(2, 12)	20508.65	20508.665(.026)	3.314	35.468	34.784	
15(1, 14)	14(2, 13)	33125.57	33125.570(.027)	3.689	40.309	39.205	73B
12(2, 10)	13(1, 13)	36803.78	36803.782(.034)	1.778	30.792	29.564	
16(2, 14)	17(1, 17)	20517.79	20517.749(.031)	1.833	49.325	48.641	
17(2, 15)	18(1, 18)	17949.31	17949.310(.032)	1.792	54.772	54.173	
18(2, 16)	19(1, 19)	16037.47	16037.484(.034)	1.736	60.546	60.011	
19(2, 17)	20(1, 20)	14803.25	14803.238(.035)	1.665	66.647	66.153	
20(2, 18)	21(1, 21)	14262.95	14262.938(.036)	1.585	73.075	72.599	
21(2, 19)	22(1, 22)	14428.13	14428.170(.034)	1.498	79.831	79.349	
22(2, 20)	23(1, 23)	15305.76	15305.743(.035)	1.407	86.914	86.403	
23(2, 21)	24(1, 24)	16897.89	16897.853(.052)	1.315	94.324	93.760	
7(2, 6)	7(1, 7)	141741.689	141741.682(.034)	3.504	14.875	10.147	
18(3, 16)	19(2, 17)	31463.95	31463.890(.037)	3.479	67.696	66.647	73B
19(3, 17)	20(2, 18)	19285.11	19285.064(.032)	3.717	73.718	73.075	
23(2, 21)	22(3, 20)	19053.23	19053.223(.032)	4.463	94.324	93.688	
24(2, 22)	23(3, 21)	32420.50	32420.471(.038)	4.727	102.061	100.980	
20(3, 17)	21(2, 20)	35461.62	35461.638(.035)	3.543	80.112	78.929	
22(3, 19)	23(2, 22)	20748.66	20748.697(.031)	3.779	93.782	93.090	
23(3, 20)	24(2, 23)	13892.38	13892.408(.030)	3.868	101.100	100.637	
28(2, 27)	27(3, 24)	9372.06	9372.044(.035)	4.000	133.925	133.613	
29(2, 28)	28(3, 25)	13962.20	13962.188(.040)	3.974	143.020	142.554	
30(2, 29)	29(3, 26)	17987.60	17987.609(.052)	3.924	152.423	151.823	
28(4, 25)	29(3, 26)	26343.07	26343.254(.067)	5.255	152.702	151.823	73B**
29(4, 26)	30(3, 27)	14442.14	14442.186(.056)	5.460	161.901	161.420	
32(3, 29)	31(4, 28)	10282.32	10282.303(.038)	5.870	181.598	181.255	
33(3, 30)	32(4, 29)	23135.42	23135.493(.039)	6.075	192.181	191.410	73B
34(3, 31)	33(4, 30)	36330.79	36330.763(.053)	6.283	203.094	201.882	
31(4, 27)	32(3, 30)	13752.86	13752.828(.043)	5.614	181.303	180.844	
35(3, 33)	34(4, 30)	11133.72	11133.709(.063)	5.982	213.142	212.771	

TABLE 5. The microwave spectrum of vinyl cyanide—Continued

Transition Upper state	Lower state	Observed frequency	Calculated frequency (uncertainty)	Line strength	Energy levels in cm^{-1} Upper state	Lower state	Remarks
39(5, 35)–	40(4, 36)	10192.63	10192.631(.116)	7.250	284.767	284.427	
39(5, 34)–	40(4, 37)	20554.18	20554.180(.086)	7.179	284.784	284.099	

The measurement uncertainties are as follows: for all transitions quoted to two decimal points the accuracy is assumed to be ± 0.15 MHz. Transitions quoted to three digits the uncertainty is ± 20 kHz. Data marked with ** have not been used in the fit.

Table 6. Transition Frequencies of Less Abundant Species of Vinyl Cyanide (in MHz)*)
Ref. 59A

Transition Upper State	Lower State	$^{13}CH_2{}^{12}CH^{12}C^{14}N$	$^{12}CH_2{}^{13}CH^{12}C^{14}N$	$^{12}CH_2{}^{12}CH^{13}C^{14}N$	$^{12}CH_2{}^{12}CH^{12}C^{15}N$
2(0,2) -	1(0,1)	18 468.27	18 864.66	18 882.69	18 410.10
2(1,2) -	1(1,1)	18 032.46	18 405.33	18 432.63	17 981.12
2(1,1) -	1(1,0)	18 911.15	19 331.98	19 340.26	18 846.25
3(0,3) -	2(0,2)	27 694.2	28 287.6	28 315.1	27 607.3
3(1,3) -	2(1,2)	27 047.1	27 605.5	27 646.8	26 970.0
3(1,2) -	2(1,1)	28 364.8	28 996.45	29 007.60	28 267.3
3(2,2) -	2(2,1)	27 709.7	28 304.9	28 331.6	27 622.1
3(2,1) -	2(2,0)	27 721.9	28 318.9	28 344.2	27 634.1

*) The estimated measurement accuracy is ±0.05 MHz for all J = 2 - 1 transitions and ±0.15 MHz for all others.

TABLE 7. Microwave transitions of vinyl cyanide in order of frequency

Transition Upper state – Lower state	Calculated frequency (uncertainty)	Transition Upper state – Lower state	Calculated frequency (uncertainty)
7(2, 5)– 7(2, 6)	436.787(.003)	39(4, 35)–39(4, 36)	8164.252(.051)
16(3, 13)–16(3, 14)	441.984(.008)	27(3, 24)–27(3, 25)	8974.733(.030)
1(1, 0)– 1(1, 1)	457.283(.001)	28(2, 27)–27(3, 24)	9372.044(.035)
17(3, 14)–17(3, 15)	629.477(.011)	1(0, 1)– 0(0, 0)	9485.033(.003)
8(2, 6)– 8(2, 7)	726.810(.005)	6(1, 5)– 6(1, 6)	9600.026(.014)
18(3, 15)–18(3, 16)	878.117(.013)	40(4, 36)–40(4, 37)	9835.980(.061)
9(2, 7)– 9(2, 8)	1139.589(.007)	16(2, 14)–16(2, 15)	10102.901(.025)
19(3, 16)–19(3, 17)	1202.390(.016)	39(5, 35)–40(4, 36)	10192.631(.116)
2(1, 1)– 2(1, 2)	1371.828(.002)	32(3, 29)–31(4, 28)	10282.303(.038)
20(3, 17)–20(3, 18)	1618.933(.019)	28(3, 25)–28(3, 26)	10982.127(.030)
10(2, 8)–10(2, 9)	1704.284(.010)	35(3, 33)–34(4, 30)	11133.709(.063)
21(3, 18)–21(3, 19)	2146.615(.022)	17(2, 15)–17(2, 16)	12642.148(.025)
11(2, 9)–11(2, 10)	2452.181(.013)	7(1, 6)– 7(1, 7)	12797.703(.017)
3(1, 2)– 3(1, 3)	2743.573(.005)	29(3, 26)–29(3, 27)	13318.519(.030)
22(3, 19)–22(3, 20)	2806.551(.025)	31(4, 27)–32(3, 30)	13752.828(.043)
12(2, 10)–12(2, 11)	3416.115(.016)	23(3, 20)–24(2, 23)	13892.408(.030)
23(3, 20)–23(3, 21)	3622.068(.027)	29(2, 28)–28(3, 25)	13962.188(.040)
4(1, 3)– 4(1, 4)	4572.388(.007)	20(2, 18)–21(1, 21)	14262.938(.036)
24(3, 21)–24(3, 22)	4618.582(.029)	21(2, 19)–22(1, 22)	14428.170(.034)
13(2, 11)–13(2, 12)	4629.799(.019)	29(4, 26)–30(3, 27)	14442.186(.056)
25(3, 22)–25(3, 23)	5823.401(.030)	19(2, 17)–20(1, 20)	14803.238(.035)
14(2, 12)–14(2, 13)	6127.040(.021)	6(0, 6)– 5(1, 5)	15010.671(.013)
5(1, 4)– 5(1, 5)	6858.018(.011)	22(2, 20)–23(1, 23)	15305.743(.035)
26(3, 23)–26(3, 24)	7265.421(.030)	18(2, 15)–18(2, 17)	15584.727(.024)
15(2, 13)–15(2, 14)	7940.908(.024)	2(1, 2)– 3(0, 3)	15982.553(.012)
13(1, 12)–12(2, 11)	8063.862(.026)	30(3, 27)–30(3, 28)	16014.304(.032)

TABLE 7. Microwave transitions of vinyl cyanide in order of frequency—Continued

Transition Upper state - Lower state	Calculated frequency (uncertainty)	Transition Upper state - Lower state	Calculated frequency (uncertainty)
18(2, 16)-19(1, 19)	16037.484(.034)	25(2, 23)-25(2, 24)	48864.479(.057)
10(2, 9)-11(1, 10)	16275.801(.027)	15(1, 14)-15(1, 15)	54518.605(.034)
8(1, 7)- 8(1, 8)	16449.974(.020)	6(1, 6)- 5(1, 5)	55510.560(.014)
23(2, 21)-24(1, 24)	16897.853(.052)	26(2, 24)-26(2, 25)	55512.952(.065)
17(2, 15)-18(1, 18)	17949.310(.032)	6(0, 6)- 5(0, 5)	56786.934(.014)
30(2, 29)-29(3, 26)	17987.609(.052)	6(2, 5)- 5(2, 4)	56896.814(.013)
2(1, 2)- 1(1, 1)	18513.081(.006)	6(3, 4)- 5(3, 3)	56936.193(.012)
19(2, 17)-19(2, 18)	18953.136(.023)	6(4, 3)- 5(4, 2)	56936.492(.011)
2(0, 2)- 1(0, 1)	18966.535(.005)	6(4, 2)- 5(4, 1)	56936.494(.011)
23(2, 21)-22(3, 20)	19053.223(.032)	6(3, 3)- 5(3, 2)	56937.116(.012)
31(3, 28)-31(3, 29)	19098.682(.035)	6(5)- 5(5)	56942.531(.011)
19(3, 17)-20(2, 18)	19285.064(.032)	6(2, 4)- 5(2, 3)	57018.189(.013)
2(1, 1)- 1(1, 0)	19427.625(.005)	6(1, 5)- 5(1, 4)	58252.568(.014)
14(1, 13)-13(2, 12)	20508.665(.026)	16(1, 15)-16(1, 16)	61681.428(.039)
16(2, 14)-17(1, 17)	20517.749(.031)	27(2, 25)-27(2, 26)	62630.153(.070)
39(5, 34)-40(4, 37)	20554.180(.086)	7(1, 7)- 6(1, 6)	64749.013(.016)
9(1, 8)- 9(1, 9)	20555.286(.022)	7(0, 7)- 6(0, 6)	66198.348(.016)
22(3, 19)-23(2, 22)	20748.697(.031)	7(2, 6)- 6(2, 5)	66370.045(.015)
32(3, 29)-32(3, 30)	22598.978(.038)	7(4, 4)- 6(4, 3)	66428.613(.013)
20(2, 18)-20(2, 19)	22765.942(.023)	7(4, 3)- 6(4, 2)	65428.621(.013)
33(3, 30)-32(4, 29)	23135.493(.039)	7(3, 5)- 6(3, 4)	66430.843(.014)
10(1, 9)-10(1, 10)	25111.476(.024)	7(3, 4)- 6(3, 3)	66432.921(.014)
7(0, 7)- 6(1, 6)	25698.459(.014)	7(5)- 6(5)	66434.343(.012)
1(1, 1)- 2(0, 2)	25910.454(.013)	7(6)- 6(6)	66444.788(.013)
28(4, 25)-29(3, 26)	26343.254(.067)	7(2, 5)- 6(2, 4)	66563.902(.015)
33(3, 30)-33(3, 31)	26540.007(.042)	7(1, 6)- 6(1, 5)	67946.690(.015)
21(2, 19)-21(2, 20)	27037.625(.025)	17(1, 16)-17(1, 17)	69249.829(.046)
3(1, 3)- 2(1, 2)	27767.352(.008)	28(2, 26)-28(2, 27)	70207.624(.073)
9(2, 8)-10(1, 9)	28156.408(.027)	8(1, 8)- 7(1, 7)	73981.556(.017)
3(0, 3)- 2(0, 2)	28440.981(.008)	8(0, 8)- 7(0, 7)	75585.695(.017)
3(2, 2)- 2(2, 1)	28456.932(.008)	8(2, 7)- 7(2, 6)	75838.866(.016)
3(2, 1)- 2(2, 0)	28470.834(.008)	8(4, 5)- 7(4, 4)	75921.978(.013)
3(1, 2)- 2(1, 1)	29139.097(.008)	8(4, 4)- 7(4, 3)	75922.000(.013)
11(1, 10)-11(1, 11)	30115.634(.026)	8(5)- 7(5)	75926.795(.013)
18(3, 16)-19(2, 17)	31463.890(.037)	8(3, 6)- 7(3, 5)	75927.705(.014)
22(2, 20)-22(2, 21)	31778.598(.030)	8(3, 5)- 7(3, 4)	75931.857(.014)
24(2, 22)-23(3, 21)	32420.471(.038)	8(6)- 7(6)	75937.822(.013)
15(1, 14)-14(2, 13)	33125.570(.027)	8(7)- 7(7)	75953.111(.016)
20(3, 17)-21(2, 20)	35461.638(.035)	8(2, 6)- 7(2, 5)	76128.889(.015)
12(1, 11)-12(1, 12)	35563.945(.027)	18(1, 17)-18(1, 18)	77210.979(.052)
35(3, 32)-35(3, 33)	35827.716(.069)	8(1, 7)- 7(1, 6)	77633.827(.016)
34(3, 31)-33(4, 30)	36330.763(.053)	29(2, 27)-29(2, 28)	78234.756(.076)
8(0, 8)- 7(1, 7)	36535.141(.015)	9(1, 9)- 8(1, 8)	83207.509(.017)
12(2, 10)-13(1, 13)	36803.782(.034)	9(0, 9)- 8(0, 8)	84946.004(.017)
23(2, 21)-23(2, 22)	36995.369(.038)	9(2, 8)- 8(2, 7)	85302.654(.016)
4(1, 4)- 3(1, 3)	37018.923(.011)	9(4, 6)- 8(4, 5)	85416.762(.014)
4(0, 4)- 3(0, 3)	37904.851(.010)	9(4, 5)- 8(4, 4)	85416.813(.014)
4(2, 3)- 3(2, 2)	37939.628(.010)	9(5)- 8(5)	85419.979(.013)
4(3, 2)- 3(3, 1)	37952.634(.009)	9(3, 7)- 8(3, 6)	85426.932(.015)
4(3, 1)- 3(3, 0)	37952.733(.009)	9(6)- 8(6)	85431.223(.014)
4(2, 2)- 3(2, 1)	37974.369(.010)	9(3, 6)- 8(3, 5)	85434.538(.015)
4(1, 3)- 3(1, 2)	38847.738(.010)	9(7)- 8(7)	85447.736(.016)
8(2, 7)- 9(1, 8)	39836.197(.027)	9(8)- 8(8)	85468.411(.020)
13(1, 12)-13(1, 13)	41451.528(.028)	19(1, 18)-19(1, 19)	85549.977(.058)
24(2, 22)-24(2, 23)	42690.811(.048)	9(2, 7)- 8(2, 6)	85715.433(.016)
5(1, 5)- 4(1, 4)	46266.935(.013)	30(2, 28)-30(2, 29)	86698.950(.091)
5(0, 5)- 4(0, 4)	47354.650(.013)	9(1, 8)- 8(1, 7)	87312.821(.017)
5(2, 4)- 4(2, 3)	47419.799(.012)	10(1, 10)- 9(1, 9)	92426.253(.017)
5(3, 3)- 4(3, 2)	47443.542(.011)	20(1, 19)-20(1, 20)	94249.732(.061)
5(3, 2)- 4(3, 1)	47443.889(.011)	10(0, 10)- 9(0, 9)	94276.638(.018)
5(4, 2)- 4(4, 1)	47445.440(.010)	10(2, 9)- 9(2, 8)	94760.788(.016)
5(4, 1)- 4(4, 0)	47445.440(.010)	10(4, 7)- 9(4, 6)	94913.134(.014)
5(2, 3)- 4(2, 2)	47489.234(.012)	10(4, 6)- 9(4, 5)	94913.246(.014)
14(1, 13)-14(1, 14)	47772.261(.031)	10(5)- 9(5)	94913.985(.013)
5(1, 4)- 4(1, 3)	48552.566(.012)	10(6)- 9(6)	94925.036(.015)

TABLE 7. Microwave transitions of vinyl cyanide in order of frequency—Continued

Transition Upper state – Lower state	Calculated frequency (uncertainty)
10(3, 8)- 9(3, 7)	94928.619(.015)
10(3, 7)- 9(3, 6)	94941.643(.015)
10(7)- 9(7)	94942.531(.017)
10(8)- 9(8)	94964.955(.021)
10(9)- 9(9)	94991.592(.027)
10(2, 8)- 9(2, 7)	95325.484(.016)
31(2, 29)-31(2, 30)	95585.727(.128)
10(1, 9)- 9(1, 8)	96982.443(.017)
11(1, 11)-10(1, 10)	101637.236(.017)
21(1, 20)-21(1, 21)	103290.891(.060)
11(0, 11)-10(0, 10)	103575.400(.018)
11(2, 10)-10(2, 9)	104212.654(.016)
11(5, 7)-10(5, 6)	104408.903(.013)
11(5, 6)-10(5, 5)	104408.904(.013)
11(4, 8)-10(4, 7)	104411.262(.013)
11(4, 7)-10(4, 6)	104411.485(.013)
11(6)-10(6)	104419.308(.015)
11(3, 9)-10(3, 8)	104432.793(.015)
11(7)-10(7)	104437.516(.017)
11(3, 8)-10(3, 7)	104453.927(.015)
11(8)-10(8)	104461.515(.021)
11(9)-10(9)	104490.361(.027)
11(10)-10(10)	104523.548(.035)
32(2, 30)-32(2, 31)	104878.790(.195)
11(2, 9)-10(2, 8)	104960.550(.016)
11(1, 10)-10(1, 9)	106641.394(.017)
12(1, 12)-11(1, 11)	110839.981(.017)
22(1, 21)-22(1, 22)	112651.805(.057)
12(0, 12)-11(0, 11)	112840.648(.017)
12(2, 11)-11(2, 10)	113657.642(.016)
12(5, 8)-11(5, 7)	113904.823(.013)
12(5, 7)-11(5, 6)	113904.825(.013)
12(4, 9)-11(4, 8)	113911.307(.013)
12(4, 8)-11(4, 7)	113911.724(.013)
12(6)-11(6)	113914.082(.015)
12(7)-11(7)	113932.707(.018)
12(3, 10)-11(3, 9)	113939.410(.014)
12(8)-11(8)	113958.092(.021)
12(3, 9)-11(3, 8)	113972.228(.014)
12(9)-11(9)	113989.016(.026)
12(10)-11(10)	114024.832(.034)
33(2, 31)-33(2, 32)	114560.051(.296)
12(2, 10)-11(2, 9)	114621.577(.016)
12(1, 11)-11(1, 10)	116288.292(.017)
13(1, 13)-12(1, 12)	120034.083(.016)
13(0, 13)-12(0, 12)	122071.413(.017)
23(1, 22)-23(1, 23)	122308.565(.055)
13(2, 12)-12(2, 11)	123095.151(.015)
13(5, 9)-12(5, 8)	123401.834(.013)
13(5, 8)-12(5, 7)	123401.840(.013)
13(6)-12(6)	123409.404(.015)
13(4, 10)-12(4, 9)	123413.425(.013)
13(4, 9)-12(4, 8)	123414.165(.013)
13(7)-12(7)	123428.124(.018)
13(3, 11)-12(3, 10)	123448.353(.014)
13(8)-12(8)	123454.687(.021)
13(9)-12(9)	123487.549(.025)
13(3, 10)-12(3, 9)	123497.472(.014)
13(10)-12(10)	123525.891(.033)
13(2, 11)-12(2, 10)	124308.835(.015)
34(2, 32)-34(2, 33)	124609.627(.435)
13(1, 12)-12(1, 11)	125921.667(.017)
14(1, 14)-13(1, 13)	129219.221(.016)
14(0, 14)-13(0, 13)	131267.478(.017)
24(1, 23)-24(1, 24)	132235.114(.069)
14(2, 13)-13(2, 12)	132524.590(.015)
23(1, 22)-23(0, 23)	132555.555(.043)
14(5, 10)-13(5, 9)	132900.027(.013)
14(5, 9)-13(5, 8)	132900.038(.013)
14(6)-13(6)	132905.317(.015)
14(4, 11)-13(4, 10)	132917.762(.012)
14(4, 10)-13(4, 9)	132919.017(.012)
14(7)-13(7)	132923.783(.018)
14(8)-13(8)	132951.302(.021)
14(3, 12)-13(3, 11)	132959.423(.013)
14(9)-13(9)	132985.947(.024)
14(10)-13(10)	133026.706(.030)
14(3, 11)-13(3, 10)	133030.680(.013)
14(11, 3)-13(11, 2)	133072.990(.043)
14(2, 12)-13(2, 11)	134021.830(.015)
14(1, 13)-13(1, 12)	135539.954(.016)
17(0, 17)-16(1, 16)	136855.594(.026)
15(1, 15)-14(1, 14)	138395.151(.016)
15(0, 15)-14(0, 14)	140429.438(.017)
24(1, 23)-24(0, 24)	141277.461(.058)
7(2, 6)- 7(1, 7)	141741.682(.034)
15(2, 14)-14(2, 13)	141945.379(.015)
15(5, 11)-14(5, 10)	142399.489(.014)
15(5, 10)-14(5, 9)	142399.510(.014)
15(6)-14(6)	142401.867(.016)
25(1, 24)-25(1, 25)	142403.431(.112)
15(7)-14(7)	142419.704(.019)
15(4, 12)-14(4, 11)	142424.454(.013)
15(4, 11)-14(4, 10)	142426.506(.013)
15(8)-14(8)	142447.936(.021)
15(3, 13)-14(3, 12)	142472.348(.013)
15(9)-14(9)	142484.201(.022)
15(10)-14(10)	142527.259(.027)
15(3, 12)-14(3, 11)	142572.970(.013)
15(11)-14(11)	142576.393(.040)
12(1, 12)-11(0, 11)	142759.353(.027)
15(2, 13)-14(2, 12)	143759.247(.015)
15(1, 14)-14(1, 13)	145141.495(.017)
16(1, 16)-15(1, 15)	147561.708(.017)
16(0, 16)-15(0, 15)	149558.702(.017)
16(2, 15)-15(2, 14)	151356.951(.015)
16(6, 11)-15(6, 10)	151899.097(.018)
16(6, 10)-15(6, 9)	151899.097(.018)
16(5, 12)-15(5, 11)	151900.309(.015)
16(5, 11)-15(5, 10)	151900.347(.015)
16(7)-15(7)	151915.902(.021)
16(4, 13)-15(4, 12)	151933.624(.014)
16(4, 12)-15(4, 11)	151936.868(.014)
16(8)-15(8)	151944.590(.022)
16(9)-15(9)	151982.298(.022)
16(3, 14)-15(3, 13)	151986.773(.014)
16(10)-15(10)	152027.529(.024)
16(3, 13)-15(3, 12)	152125.561(.014)
26(1, 25)-26(1, 26)	152783.822(.185)
16(2, 14)-15(2, 13)	153518.944(.016)
16(1, 15)-15(1, 14)	154724.531(.017)
17(1, 17)-16(1, 16)	156718.809(.018)
17(0, 17)-16(0, 16)	158657.432(.018)
17(2, 16)-16(2, 15)	160758.759(.017)
17(6, 12)-16(6, 11)	161397.050(.021)
17(6, 11)-16(6, 10)	161397.051(.021)
17(5, 13)-16(5, 12)	161402.574(.018)
17(5, 12)-16(5, 11)	161402.641(.018)
17(7)-16(7)	161412.397(.024)
17(8)-16(8)	161441.265(.025)

TABLE 7. Microwave transitions of vinyl cyanide in order of frequency—Continued

Transition Upper state–Lower state	Calculated frequency (uncertainty)
17(4, 14)–16(4, 13)	161445.382(.016)
17(4, 13)–16(4, 12)	161450.362(.016)
17(9)–16(9)	161480.229(.025)
17(3, 15)–16(3, 14)	161502.271(.016)
17(10)–16(10)	161527.499(.025)
17(3, 14)–16(3, 13)	161689.763(.016)
17(2, 15)–16(2, 14)	163298.006(.018)
27(1, 26)–27(1, 27)	163345.300(.290)
17(1, 16)–16(1, 15)	164287.210(.019)
18(1, 18)–17(1, 17)	165866.445(.020)
18(0, 18)–17(0, 17)	167728.434(.020)
18(2, 17)–17(2, 16)	170150.272(.019)
18(6, 13)–17(6, 12)	170895.771(.025)
18(6, 12)–17(6, 11)	170895.772(.025)
18(5, 14)–17(5, 13)	170906.370(.021)
18(5, 13)–17(5, 12)	170906.484(.021)
18(7)–17(7)	170909.204(.028)
18(8)–17(8)	170937.960(.030)
18(4, 15)–17(4, 14)	170959.817(.019)
18(4, 14)–17(4, 13)	170967.269(.019)
18(9)–17(9)	170977.981(.030)
18(3, 16)–17(3, 15)	171018.336(.018)
18(10)–17(10)	171027.147(.030)
18(3, 15)–17(3, 14)	171266.976(.018)
18(2, 16)–17(2, 15)	173092.852(.020)
18(1, 17)–17(1, 16)	173827.595(.021)
28(1, 27)–28(1, 28)	174056.053(.429)
19(1, 19)–18(1, 18)	175004.678(022)
19(0, 19)–18(0, 18)	176774.996(.023)
19(2, 18)–18(2, 17)	179530.985(.022)
19(6, 14)–18(6, 13)	180395.303(.030)
19(6, 13)–18(6, 12)	180395.305(.030)
19(7)–18(7)	180406.340(.035)
19(5, 15)–18(5, 14)	180411.784(.025)
19(5, 14)–18(5, 13)	180411.971(.025)
19(8)–18(8)	180434.677(.038)
19(9)–18(9)	180475.543(.039)
19(4, 16)–18(4, 15)	180476.998(.022)
19(4, 15)–18(4, 14)	180487.898(.022)
19(10)–18(10)	180526.455(.040)
19(3, 17)–18(3, 16)	180534.396(.022)
19(11)–18(11)	180585.994(.045)
19(12)–18(12)	180653.285(.065)
19(3, 16)–18(3, 15)	180858.669(.021)
19(2, 17)–18(2, 16)	182899.394(.024)
19(1, 18)–18(1, 17)	183343.676(.024)
20(1, 20)–19(1, 19)	184133.640(.026)
29(1, 28)–29(1, 29)	184884.004(.609)
20(0, 20)–19(0, 19)	185800.697(.026)
20(2, 19)–19(2, 18)	188900.417(.025)
20(6, 15)–19(6, 14)	189895.689(.037)
20(6, 14)–19(6, 13)	189895.692(.037)
20(7)–19(7)	189903.823(.043)
20(5, 16)–19(5, 15)	189918.900(.031)
20(5, 15)–19(5, 14)	189919.198(.031)
20(8)–19(8)	189931.414(.049)
20(9)–19(9)	189972.905(.052)
20(4, 17)–19(4, 16)	189996.968(.027)
20(4, 16)–19(4, 15)	190012.590(.027)
20(3, 18)–19(3, 17)	190049.815(.026)
20(3, 17)–19(3, 16)	190466.359(.025)
20(2, 18)–19(2, 17)	192713.222(.028)
20(1, 19)–19(1, 18)	192833.396(.027)
21(1, 21)–20(1, 20)	193253.522(.030)
21(0, 21)–20(0, 20)	194809.207(.030)
30(1, 29)–30(1, 30)	195797.420(.836)
21(2, 20)–20(2, 19)	198258.117(.029)
21(6, 16)–20(6, 15)	199396.972(.045)
21(6, 15)–20(6, 14)	199396.977(.045)
21(7)–20(7)	199401.668(.054)
21(5, 17)–20(5, 16)	199427.798(.038)
21(8)–20(8)	199428.172(.062)
21(5, 16)–20(5, 15)	199428.263(.038)
21(9)–20(9)	199470.053(.068)
21(4, 18)–20(4, 17)	199519.744(.033)
21(4, 17)–20(4, 16)	199541.725(.033)
21(3, 19)–20(3, 18)	199563.899(.031)
21(3, 18)–20(3, 17)	200091.580(.030)
21(1, 20)–20(1, 19)	202294.681(.031)
21(2, 19)–20(2, 18)	202529.800(.032)

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