

Analysis of the terahertz rotational spectrum of the three mono-¹³C ethyl cyanides (¹³C–CH₃CH₂CN)^{*}

C. Richard¹, L. Margulès¹, R. A. Motiyenko¹, and J.-C. Guillemin²

¹ Laboratoire de Physique des Lasers, Atomes et Molécules, UMR CNRS 8523, Université Lille 1, 59655 Villeneuve d'Ascq Cedex, France

e-mail: cyril.richard@phlam.univ-lille1.fr, laurent.margules@univ-lille1.fr

² Institut des Sciences Chimiques de Rennes, UMR 6226 CNRS – ENSCR, Avenue du Général Leclerc, CS 50837, 35708 Rennes Cedex 7, France

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ABSTRACT

Context. Millimeter- and submillimeter-wave spectra of regions such as the Orion molecular cloud show many rotational-torsional lines that are caused by the emission of complex organic molecules (COM). Previous laboratory investigations have been conducted for three isotopologues of ethyl cyanide up to 360 GHz, and subsequently, several hundred lines of the three isotopologues have been detected in Orion IRC2 using the IRAM 30 m radiotelescope.

Aims. In this survey we present the analysis based on a Watson Hamiltonian for an asymmetric one-top rotor of the ¹³C-substituted ethyl cyanide ¹³CH₃CH₂CN, CH₃¹³CH₂CN and CH₃CH₂¹³CN in the frequency range 480–650 GHz and 780–990 GHz.

Methods. The rotational spectra of the three species were measured with a submillimeter spectrometer (50–990 GHz) using solid-state sources.

Results. A new set of spectroscopic parameters was determined from a least-squares fit procedure for each isotopologue. These parameters permit a new accurate prediction of rotational lines suitable for an astrophysical detection in the submillimeter wave range.

Key words. line: identification – methods: laboratory – molecular data – techniques: spectroscopic – submillimeter: ISM – ISM: molecules

1. Introduction

Ethyl cyanide, also known as propanenitrile or propionitrile, has been observed in abundance in hot molecular clouds in the range 40–950 GHz (Johnson et al. 1977; Blake et al. 1987, 1996; Schilke et al. 2001; White et al. 2003; Comito et al. 2005). The three ¹³C isotopologues of CH₃CH₂CN have been observed in Orion (Demyk et al. 2007). Furthermore, 193, 161 and 208 lines, respectively, from the ¹³CH₃CH₂CN, CH₃¹³CH₂CN and the CH₃CH₂¹³CN in the region of 8–40 GHz and 160–360 GHz, have also been assigned and fitted.

This paper proposes a re-investigation of the ground-state rotational spectrum of ¹³C-substituted ethyl cyanide (CH₃CH₂CN) and we present the analysis of spectra of up to 990 GHz for both μ_a and μ_b transitions.

2. Experimental details

2.1. Synthesis of the three species

Into a three-necked flask equipped with a stirring bar, a reflux condenser, and a nitrogen inlet, we introduced triethylene glycol (20 mL), potassium cyanide (0.7 g, 10.7 mmol), and ethyl iodide-2-¹³C (1 g, 6.4 mmol). The mixture was heated to 110 °C and stirred at this temperature for one hour. After cooling at room temperature, the flask was fitted on a vacuum line equipped with two U-tubes. The high boiling

compounds were condensed in the first trap cooled at –30 °C and propanenitrile-3-¹³C (¹³CH₃CH₂CN) was selectively condensed in the second trap cooled at –90 °C.

The same approach was used with propanenitrile-2-¹³C (CH₃¹³CH₂CN) (1 g, 6.4 mmol).

Propanenitrile-1-¹³C (CH₃CH₂¹³CN) was prepared with the same approach starting from K¹³CN, (1 g, 15 mmol) and an excess of ethyl iodide (2.7 g, 17.3 mmol). The nuclear magnetic resonance spectroscopy (NMR) of the three isotopologues is given in Appendix A.

2.2. Lille – submillimeter wave spectrometer

The submillimeter-wave measurements were performed using the Lille spectrometer (150–990 GHz) (Motiyenko et al. 2010). The sources are only solid-state devices. The frequency of the Agilent synthesizer (12.5–17.5 GHz) was first multiplied by six and amplified by a Spacek active sextupler providing the output power of +15 dBm in the W-band range (75–110 GHz). This power is sufficiently high to use passive Schottky multipliers (×2, ×3, ×5, ×2×3, ×3×3) from Virginia Diodes Inc. in the next stage of frequency multiplication chain. As a detector we used an InSb liquid He-cooled bolometer from QMC Instruments Ltd. to improve the sensitivity of the spectrometer, the sources were frequency modulated at 10 kHz. The absorption cell was a stainless-steel tube (6 cm diameter, 220 cm long). The sample pressure during measurements was about 1.5 Pa (15 μbar) and the linewidth was limited by Doppler broadening. These measurements were performed at

* Full Tables B.1–B.3 are only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via <http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/543/A135>

Table 1. Spectroscopic constants of the ground-vibrational state of $^{13}\text{C}-\text{CH}_3\text{CH}_2\text{CN}$, A-reduction.

	$^{13}\text{CH}_3\text{CH}_2\text{CN}$		$\text{CH}_3^{13}\text{CH}_2\text{CN}$		$\text{CH}_3\text{CH}_2^{13}\text{CN}$	
A/MHz	27 342.63773	(51)	27 045.84363	(38)	27 635.42032	(36)
B/MHz	4598.064016	(89)	4697.959450	(71)	4689.912975	(66)
C/MHz	4133.742548	(92)	4207.097999	(64)	4214.778898	(58)
Δ_J/kHz	2.992921	(26)	2.992961	(22)	3.034021	(22)
Δ_{JK}/kHz	-48.38307	(23)	-45.08507	(23)	-47.84327	(22)
Δ_K/kHz	546.4137	(40)	525.9986	(28)	554.0047	(29)
δ_J/kHz	0.662708	(15)	0.683922	(10)	0.676863	(10)
δ_K/kHz	12.0680	(15)	12.7168	(15)	12.4949	(14)
Φ_J/Hz	0.0099677	(35)	0.0098115	(30)	0.0099637	(32)
Φ_{JK}/Hz	-0.04585	(16)	-0.01975	(20)	-0.03851	(23)
Φ_{KJ}/Hz	-1.88899	(95)	-1.87981	(95)	-1.8559	(10)
Φ_K/Hz	31.536	(14)	30.3286	(95)	31.838	(10)
ϕ_J/Hz	0.0037983	(28)	0.0038469	(23)	0.0038691	(22)
ϕ_{JK}/Hz	0.08583	(14)	0.09247	(13)	0.09030	(13)
ϕ_K/Hz	5.523	(12)	5.702	(13)	5.824	(15)
L_J/mHz	-0.00004170	(15)	-0.00003903	(13)	-0.00003980	(15)
L_{JK}/mHz			-0.0001768	(25)	-0.0000644	(28)
L_{JK}/mHz	-0.005993	(53)	-0.006546	(43)	-0.006711	(41)
L_{KKJ}/mHz	0.09609	(81)	0.09995	(42)	0.09198	(28)
L_K/mHz	-2.033	(16)	-2.029	(10)	-2.098	(12)
$l_J/\mu\text{Hz}$	-0.01942	(15)	-0.01981	(13)	-0.02033	(13)
Lines ^a	1845		1835		1976	
L_{worst}^b	4.0		-3.6		3.7	
n^c	20		21		21	
s^d	39		38		38	
η^e	265		360		424	

Notes. ^(a) Number of distinct lines in the fit. ^(b) (o.-c.)/error of the poorest-fit line. ^(c) Number of free parameters used in the fit. ^(d) Standard deviation of the fit in kHz. ^(e) Condition number (Belsley 1991; Demaison et al. 1994).

room temperature. The measurement accuracy for isolated lines is estimated to be better than 30 kHz up to 630 GHz and 50 kHz above, owing to the Doppler effect. However, if the lines were blended or had a poor signal-to-noise ratio, they were given a lighter weight.

3. Analysis

Ethyl cyanide is a near-prolate asymmetric top ($\kappa = -0.96$ MHz), it has a large a-dipole moment component ($\mu_a = 3.85$ D) and a smaller b-dipole moment component ($\mu_b = 1.23$ D) (Heise et al. 1973). In consequence, the spectrum contains both a- and b-type transitions.

For each isotopologue of $^{13}\text{C}-\text{CH}_3\text{CH}_2\text{CN}$, preliminary predictions and fits of rotational spectra were carried out with programs ASROT and ASFIT (Kisiel 2001), using the standard rotational Hamiltonian in Watson's A- and S-reduction in I' representation (Watson 1977). This analysis was undertaken as a subsequent work of Demyk et al. (2007) in the region of 8–40 GHz and 160–360 GHz. Previous parameters and assigned transitions were used for the initial prediction in A-reduction. Then, the prediction was improved step by step while adding new identified lines. Once all new lines were assigned, the spectroscopic parameters were also determined in S-reduction with the same set of data. Even if in the original set of spectroscopic parameters the use of five quartics and seven sextic distortion constants was sufficient to fit the data, the addition of five or eight octic constants was necessary in our survey. As discussed in the previous work, these three species show a very dense spectrum and some lines are either blended or distorted.

In consequence, some distorted lines are not included in the fit but blended transitions, with their relative intensities, are assigned as such. In addition, we assumed that the value of the dipole moment of the ^{13}C -isotopologues can be approximated to the value of the ^{12}C species: the spectrum contains mainly ^aR-branch and ^bR- and ^bQ-branch.

The spectroscopic parameters and their uncertainty are presented in Tables 1 and 2 in A- and S-reduction.

For $^{13}\text{CH}_3\text{CH}_2\text{CN}$, 1845 lines (1653 new lines) were fitted, including 1081 (946 new lines) μ_a and 764 (707 new lines) μ_b transitions: a short example is listed in Table B.1 and all experimental frequencies of the three isotopologues are available in electronic form at the CDS. One line from the previous study was removed from the final fit because of higher residuals (more than 4σ). The lines were fitted with a J value up to 99 and a K_a value up to 28. The standard deviation of the fit in A-reduction is 39 kHz and all parameters were well determined except for L_{JK} . Fixing its value to the value given by Brauer et al. (2009) for the ^{12}C species, $L_{JK} = -0.0814 \mu\text{Hz}$, made the fit poorer. In consequence, its value was fixed to zero. We used the same set of data for the S-reduction and derived a fit with a standard deviation of 35 kHz and well determined S-parameters.

1835 μ_a and μ_b transitions (1684 new lines) were assigned and included in the fit for $\text{CH}_3^{13}\text{CH}_2\text{CN}$, 1007 and 678 new μ_a and μ_b lines, respectively. Nevertheless, ten lines from the previous work were removed. Table B.2 gives a short example of the measured transitions. The total of the transitions was fitted with $0 \leq J \leq 100$ and a K_a value up to 30. The fit in A- and S-reduction gives a standard deviation of 38 kHz and 36 kHz, respectively. All parameters are well determined in both cases.

Table 2. Spectroscopic constants of the ground-vibrational state of $^{13}\text{C}-\text{CH}_3\text{CH}_2\text{CN}$, S-reduction.

	$^{13}\text{CH}_3\text{CH}_2\text{CN}$		$\text{CH}_3^{13}\text{CH}_2\text{CN}$		$\text{CH}_3\text{CH}_2^{13}\text{CN}$	
A/MHz	27 342.64243	(46)	27 045.84757	(36)	27 635.42549	(35)
B/MHz	4598.040292	(85)	4697.934381	(69)	4689.888265	(64)
C/MHz	4133.766720	(87)	4207.123609	(61)	4214.804072	(57)
D_J/kHz	2.932282	(22)	2.924262	(19)	2.970349	(20)
D_{JK}/kHz	-48.01346	(20)	-44.66720	(21)	-47.45471	(20)
D_K/kHz	546.1249	(36)	525.6656	(27)	553.7043	(29)
d_1/kHz	-0.662631	(14)	-0.683805	(11)	-0.676751	(10)
d_2/kHz	-0.0304399	(88)	-0.0344815	(75)	-0.0319500	(65)
H_J/Hz	0.0090743	(30)	0.0088080	(27)	0.0090242	(30)
H_{JK}/Hz	-0.123202	(34)	-0.105973	(38)	-0.1214478	(41)
H_{KJ}/Hz	-1.59902	(62)	-1.55609	(47)	-1.53950	(40)
H_K/Hz	31.363	(12)	30.1157	(90)	31.650	(10)
h_1/Hz	0.0037426	(26)	0.0037748	(24)	0.0038048	(24)
h_2/Hz	0.0004658	(19)	0.0005274	(17)	0.0004921	(15)
h_3/Hz	0.00005550	(56)	0.00006320	(57)	0.00005898	(51)
L_J/mHz	-0.00003623	(14)	-0.00003338	(13)	-0.00003448	(14)
L_{JK}/mHz	0.0005208	(18)	0.0004181	(19)	0.0005343	(21)
L_{JK}/mHz	-0.005073	(49)	-0.005814	(43)	-0.006945	(37)
L_{KKJ}/mHz	0.07034	(72)	0.07324	(38)	0.06672	(25)
L_K/mHz	-2.035	(15)	-2.016	(10)	-2.114	(12)
$l_1/\mu\text{Hz}$	-0.01843	(13)	-0.01842	(13)	-0.01916	(13)
$l_2/\mu\text{Hz}$	-0.00360	(11)	-0.00421	(10)	-0.003939	(90)
$l_3/\mu\text{Hz}$	-0.000867	(52)	-0.000849	(52)	-0.000902	(48)
Lines ^a	1845		1835		1976	
L_{worst}^b	-3.4		-3.9		-3.9	
n^c	23		23		23	
s^d	35		36		38	
η^e	232		193		186	

Notes. ^(a) Number of distinct lines in the fit. ^(b) (o.-c.)/error of the poorest-fit line. ^(c) Number of free parameters used in the fit. ^(d) Standard deviation of the fit in kHz. ^(e) Condition number (Belsley 1991; Demaison et al. 1994).

For $\text{CH}_3\text{CH}_2^{13}\text{CN}$, the fit includes 1976 distinct lines (1771 new lines), 1164 μ_a (1083 new lines) and 812 μ_b (688 new lines): a short example is listed in Table B.3. Three lines were removed from the original fit and the J value up to 100 and the K_a value up to 33. The result of the fit in A-reduction has a standard deviation of 38 kHz and all the parameters are well determined. For the S-reduction the standard deviation is the same and the S-parameters are also well determined.

4. Discussion

The ground-state rotational spectrum of ^{13}C -substituted ethyl cyanide ($\text{CH}_3\text{CH}_2\text{CN}$) was measured and analysed in a new frequency range, up to 1 THz. Data from this current investigation were combined with published data from Demyk et al. (2007) into a global fit for each species. As a rule, some lines were excluded from the fit if their residual was higher than 4σ . All experimental frequencies are given in Tables B.1–B.3 and are only available in electronic form at the CDS. As we could expect, regarding the previous work on the ^{12}C species (Brauer et al. 2009), both A- and S-reduction of this work gave similar results. One of these fits (fit of $^{13}\text{CH}_3\text{CH}_2\text{CN}$) is slightly better in S-reduction (35 kHz vs. 39 kHz), but there are three additional parameters and the two condition numbers are very

Table 3. Comparison between observed frequency and preliminary calculation of $\text{CH}_3^{13}\text{CH}_2\text{CN}$ for several J and K_a values.

Transitions	Observed ^a	Calculated ^b	Obs–Calc
$57_{4,54} \leftarrow 56_{4,53}$	501644.5879	501649.7265	5.1386
$69_{10,60} \leftarrow 68_{10,59}$	615550.1717	615571.9115	21.7398
$69_{10,59} \leftarrow 68_{10,58}$	615575.5959	615597.3819	21.7860
$71_{3,68} \leftarrow 70_{3,67}$	618325.3026	618343.0004	17.6978
$70_{22,48} \leftarrow 69_{22,47}$	623266.8467	623321.2705	54.4238
$91_{10,81} \leftarrow 90_{10,80}$	813903.3846	813992.2784	88.8938

Notes. Units are in MHz. ^(a) This work. ^(b) Based upon the spectroscopic parameters of Demyk et al. (2007).

similar. Therefore, no valid conclusion can be inferred from this result. For the other isotopologues, condition numbers are about twice as good in S-reduction for fits giving similar (36 kHz vs. 38 kHz) or equal (38 kHz) standard deviations, but again, fewer parameters are used in A-reduction (21 vs. 23).

Using the previous set of data from Demyk et al. (2007) to build preliminary predictions in the ALMA or *Herschel* frequency range (respectively 84–720 GHz and 500–2000 GHz), significant discrepancies between calculated and observed lines were noticed. Table 3 presents the frequency difference between

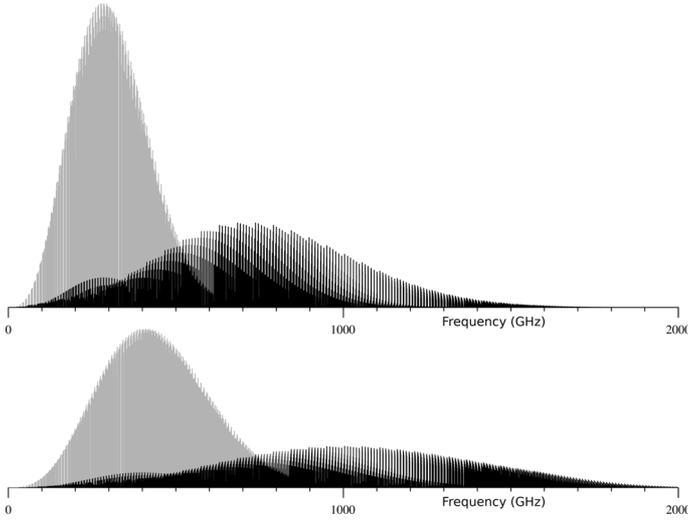


Fig. 1. Stick spectrum of $^{13}\text{CH}_3\text{CH}_2\text{CN}$ at 150 K (above) and 300 K (below) from 0 to 2 THz. The a-type spectrum is represented in grey while the b-type spectrum is shown in black. This simulation is based upon the spectroscopic constants determined in this work and was provided by the ASROT program (Kisiel 2001).

the initial predictions based upon Demyk et al. (2007) and measurements of this study for several transitions. The significance of the difference does not permit an astrophysical detection at 300 GHz and above even for the lines that are the most suitable for detection, i.e., the lines with a low K_a , and it is noticeable that the error increases with J and K_a . For example, the transition $71_{3,68} \leftarrow 70_{3,67}$ is shifted by around 18 MHz compared to our measurements. It was therefore very important to extend the measures up to 1 THz to improve the set of spectroscopic parameters, in turn obtain a more accurate set of data lines. The data are now also predictable up to higher frequency. Still, it is important to keep in mind that at high J and K_a transitions ($J > 100$, $K_a > 35$), the propagation of the uncertainties becomes non-negligible and the decic distortion constants need to be determined. Therefore, extrapolated data should be used with caution.

An additional reason to extend the measurement up to 1 THz is given in Fig. 1, which represents a simulated spectrum of $^{13}\text{CH}_3\text{CH}_2\text{CN}$. The most intense transitions of the b-type spectrum are found at 1 THz for a rotational temperature of 300 K, and in this portion of spectrum, the lines could be relevant for astrophysical detection. Indeed, even at the ISM temperature of 150 K, the intensity of these lines is sufficiently high to permit the detection up to 850 GHz with the ALMA telescope, which will be fully operational in the next years.

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Appendix A: NMR of the three isotopologues

A.1. propanenitrile-3- ^{13}C ($^{13}\text{CH}_3\text{CH}_2\text{CN}$)

Yield: 89%. ^1H NMR (CDCl_3 , 400 MHz) δ 1.29 (dt, $^1J_{\text{CH}} = 130.7$ Hz, $^3J_{\text{HH}} = 7.5$ Hz, CH_3); 2.34 (dq, $^2J_{\text{CH}} = 5.0$ Hz,

$^3J_{\text{HH}} = 7.5$ Hz, CH_2). ^{13}C NMR (CDCl_3 , 100 MHz) δ 10.6 (q, $^1J_{\text{CH}} = 130.7$ Hz, CH_3); 10.8 (t, $^1J_{\text{CH}} = 135.0$ Hz, $^1J_{\text{CC}} = 22.5$ Hz (d), CH_2); 120.8 (CN).

A.2. Propanenitrile-2- ^{13}C ($\text{CH}_3^{13}\text{CH}_2\text{CN}$)

Yield: 89%. ^1H NMR (CDCl_3 , 400 MHz) δ 1.29 (dt, $^2J_{\text{CH}} = 4.6$ Hz, $^3J_{\text{HH}} = 7.5$ Hz, CH_3); 2.34 (dq, $^1J_{\text{CH}} = 135.1$ Hz, $^3J_{\text{HH}} = 7.5$ Hz, CH_2). ^{13}C NMR (CDCl_3 , 100 MHz) δ 10.6 (q, $^1J_{\text{CH}} = 131.3$ Hz, $^1J_{\text{CC}} = 26.2$ Hz (d), CH_3); 10.8 (t, $^1J_{\text{CH}} = 135.0$ Hz, CH_2); 120.8 ($^1J_{\text{CC}} = 56.0$ Hz (d), CN).

A.3. Propanenitrile-1- ^{13}C ($\text{CH}_3\text{CH}_2^{13}\text{CN}$)

Yield: 93%. ^1H NMR (CDCl_3 , 400 MHz) δ 1.29 (dt, $^3J_{\text{CH}} = 6.8$ Hz, $^3J_{\text{HH}} = 7.5$ Hz, CH_3); 2.34 (dq, $^2J_{\text{CH}} = 9.7$ Hz, $^3J_{\text{HH}} = 7.5$ Hz, CH_2). ^{13}C NMR (CDCl_3 , 100 MHz) δ 10.6 (q, $^1J_{\text{CH}} = 131.3$ Hz, $^2J_{\text{CC}} = 2.9$ Hz (d), CH_3); 10.9 (t, $^1J_{\text{CH}} = 135.0$ Hz, $^1J_{\text{CC}} = 56.7$ Hz (d), CH_2); 120.8 (CN).

Appendix B: Example of transitions measured in the spectrum for the three isotopologues

Table B.1. Example of transitions measured in the spectrum of $^{13}\text{CH}_3\text{CH}_2\text{CN}$.

J''	K''_a	K''_c	J'	K'_a	K'_c	Obs. Freq. (MHz)	o.-c. (MHz) ^a	o.-c. (MHz) ^b	Accuracy (MHz)
47	12	36	46	11	35	936410.1024	-0.0506	-0.0356	0.0500
42	13	30	41	12	29	938423.4890	-0.0209	-0.0052	0.0500
37	14	24	36	13	23	939841.2922	0.0338	0.0483	0.0500
32	15	18	31	14	17	940844.6210	-0.0267	-0.0147	0.0500
27	16	12	26	15	11	941528.4133	-0.0315	-0.0230	0.0500
22	17	6	21	16	5	941944.4206	0.0252	0.0288	0.0500
53	11	43	52	10	42	941979.0876*	0.0037	0.0132	0.0500
53	11	42	52	10	43	941979.0876*	0.0037	0.0132	0.0500
43	13	31	42	12	30	947156.2010	0.0701	0.0853	0.0500
28	16	13	27	15	12	950335.6957	-0.0006	0.0085	0.0500
23	17	7	22	16	6	950755.7557	-0.0242	-0.0198	0.0500
18	18	1	17	17	0	950932.2935	-0.0151	-0.0179	0.0500

Notes. (*) Blended transitions. (a) A-reduction. (b) S-reduction.

Table B.2. Example of transitions measured in the spectrum of $\text{CH}_3^{13}\text{CH}_2\text{CN}$.

J''	K''_a	K''_c	J'	K'_a	K'_c	Obs. Freq. (MHz)	o.-c. (MHz) ^a	o.-c. (MHz) ^b	Accuracy (MHz)
51	21	30	51	20	31	912956.9583	-0.0222	-0.0345	0.0500
52	21	31	52	20	32	913098.4953	0.1288	0.1167	0.0500
53	21	32	53	20	33	913240.7505	-0.0602	-0.0721	0.0500
54	21	33	54	20	34	913384.3645	0.1399	0.1286	0.0500
55	21	34	55	20	35	913528.5566	0.0386	0.0281	0.0500
56	21	35	56	20	36	913673.5747	-0.0254	-0.0348	0.0500
57	21	36	57	20	37	913819.4805	0.1020	0.0941	0.0500
58	21	37	58	20	38	913965.8456	0.0857	0.0795	0.0500
59	21	38	59	20	39	914112.7139	0.0640	0.0598	0.0500
60	21	39	60	20	40	914259.9360	-0.0173	-0.0190	0.0500
61	21	40	61	20	41	914407.4668	-0.1067	-0.1057	0.0500
20	17	4	19	16	3	915418.1316	0.0091	0.0292	0.0500

Notes. (a) A-reduction. (b) S-reduction.

Table B.3. Example of transitions measured in the spectrum of $\text{CH}_3\text{CH}_2^{13}\text{CN}$.

J''	K''_a	K''_c	J'	K'_a	K'_c	Obs. Freq. (MHz)	o.-c. (MHz) ^a	o.-c. (MHz) ^b	Accuracy (MHz)
48	21	27	48	20	28	936 091.5584	0.0790	0.0794	0.0500
49	21	28	49	20	29	936 243.2666	0.1134	0.1102	0.0500
50	21	29	50	20	30	936 396.6453	0.1019	0.0956	0.0500
51	21	30	51	20	31	936 551.6542	0.0829	0.0740	0.0500
52	21	31	52	20	32	936 708.1480	-0.0095	-0.0204	0.0500
53	21	32	53	20	33	936 866.3447	0.1237	0.1113	0.0500
54	21	33	54	20	34	937 025.7675	0.0873	0.0741	0.0500
57	21	36	57	20	37	937 511.6979	0.1008	0.0892	0.0500
58	21	37	58	20	38	937 675.7102	-0.0896	-0.0992	0.0500
51	11	41	50	10	40	937 861.5085*	0.0242	0.0298	0.0500
51	11	40	50	10	41	937 861.5085*	0.0242	0.0298	0.0500
60	21	39	60	20	40	938 006.9043	-0.1265	-0.1299	0.0500

Notes. ^(*) Blended transitions. ^(a) A-reduction. ^(b) S-reduction.

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