

Transition frequencies and strengths of H₂¹⁷O and H₂¹⁸O: 6600 to 7640 cm⁻¹

Robert A. Toth

High-resolution spectra of O¹⁷- and O¹⁸-enriched water-vapor samples have been recorded with a Fourier transform spectrometer covering the region between 6600 and 7640 cm⁻¹. Experimental values of line positions and strengths of 1807 absorptions in the (120)–(000), (021)–(000), (200)–(000), (101)–(000), (002)–(000), bands of the two isotopic species were derived from the spectra. The analysis included the determination of accurate rotational levels belonging to the (120), (021), (200), (101), and (002) vibrational states of H₂¹⁷O and H₂¹⁸O.

Introduction

A recent study¹ reported line positions and strengths of over 3300 transitions of H₂¹⁶O in the region between 5750 and 7965 cm⁻¹. The present study is a similar investigation of H₂¹⁷O and H₂¹⁸O in the 6600 to 7640 cm⁻¹ region encompassing transitions in the (120)–(000), (021)–(000), (200)–(000), (101)–(000), (002)–(000) vibrational bands of both isotopic species. The line positions were analyzed to determine accurate values of the rotational energy levels in the (120), (021), (200), (101), and (002) vibrational states.

Previous studies of oxygen-enriched water-vapor spectra in this spectral region include studies by Toth *et al.*² and Chevillard *et al.*³ Toth *et al.*² measured line positions of enriched samples of H₂¹⁸O with a 0.1% impurity of H₂¹⁷O in the 6974–7387-cm⁻¹ region using a 0.07-cm⁻¹ spectral-resolution grating instrument. Chevillard *et al.*³ recorded O¹⁸-enriched water-vapor spectra between 590–8000 cm⁻¹ with a high-resolution Fourier transform spectrometer and determined rotational energy levels of the (040), (120), (021), (200), (101), (002) vibrational states. They also measured the strengths of 726 lines with a quoted average uncertainty of 6% for each measured feature. They used the curve-of-growth method in their line-strength analysis and included lines with strength values of 2.0 × 10⁻² cm⁻²/atm (normalized to 100% of the sample) and less. The strongest

Table 1. Experimental Conditions

Run	Resolu- tion ^a	Sample Pres- sure (Torr)	Sample Tem- pera- ture (K)	Path (m)	Percent abundance			
					H ₂ ¹⁶ O	H ₂ ¹⁷ O	H ₂ ¹⁸ O	HD ¹⁶ O
1	0.012	14.3	297	433	99.9	0.037	0.207	0.044
2	0.012	9.20	297	433	99.9	0.038	0.210	0.048
3	0.012	1.05	298	433	99.9	0.036	0.203	0.05
4	0.012	1.24	298	98.4	99.9	0.036	0.203	0.05
5	0.012	1.24	298	25.4	99.9	0.036	0.203	0.05
6 ^b	0.011	1.07	296	2.39	16.0	53.0	31.4	
7 ^b	0.011	5.06	296	2.39	14.3	57.1	28.0	
8 ^b	0.011	14.1	296	2.39	13.2	59.5	27.5	

^aUnapodized spectral resolution (cm⁻¹).

^bHD¹⁶O not determined.

transitions observed in this region have values of 0.2 cm⁻²/atm (normalized to 100% of the sample) and slightly greater, and the strengths of these transitions were measured in the present study.

Experimental Details

The water-vapor spectra were recorded with a FTS located in the McMath solar telescope facility at the

Table 2. Extent of H₂¹⁷O and H₂¹⁸O Measurements (cm⁻¹) Taken Under Conditions Given in Table 1

Band	H ₂ ¹⁸ O	H ₂ ¹⁷ O
(120)–(000)	6607.966–7003.043	6616.760–7000.591
(200)–(000)	6788.679–7464.665	6794.462–7456.137
(021)–(000)	6619.097–7357.251	6631.486–7173.590
(101)–(000)	6810.113–7594.919	6816.964–7569.804
(002)–(000)	6992.507–7639.314	7033.230–7639.224

The author is with the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109.

Received 20 December 1993; revised manuscript received 20 December 1993.

0003-6935/94/214868-12\$06.00/0.

© 1994 Optical Society of America.

Table 3. Rotational Energy Levels of the (101), (200), (002), (021), and (120) Vibrational States of H₂¹⁷O (cm⁻¹) and Uncertainties (cm⁻¹ × 10⁵)

J	K _a	K _c	(101)	(200)	(002)	(021)	(120)	J	K _a	K _c
0	0	0	7238.71401 40	7193.24641 50	7431.07611 300	6857.27261 40	6764.72500 50	0	0	0
1	0	1	7261.87430 40	7216.26989 25	7454.35514 30	6880.87774 10	6788.12934 50	1	0	1
1	1	1	7273.44841 12	7228.30163 50	7465.49800 40	6899.18725 10	6807.66300 300	1	1	1
1	1	0	7278.70608 10	7233.51531 50	7470.81844 50	6905.10334 40	6813.48821 50	1	1	0
2	0	2	7306.72633 20	7260.94077 10	7499.36874 50	6926.83205 20	6833.78590 50	2	0	2
2	1	2	7314.06461 15	7269.12574 30	7506.73345 40	6940.55368 15	6848.66415 15	2	1	2
2	1	1	7330.54555 10	7284.71695 40	7522.66917 50	6958.23922 20	6866.11167 50	2	1	1
2	2	1	7364.77880 15	7320.31414 20	7555.87084 50	7012.23225 15	6923.60175 15	2	2	1
2	2	0	7366.20153 35	7322.39184 20	7557.36800 300	7013.44822 10	6924.68600 300	2	2	0
3	0	3	7370.95843 18	7325.04288 35	7563.77623 50	6992.97515 40	6899.67315 60	3	0	3
3	1	3	7374.85983 10	7329.58935 30	7567.70631 50	7002.36348 30	6909.48200 300	3	1	3
3	1	2	7406.72652 20	7360.44585 30	7599.20882 50	7036.93255 50	6944.13612 50	3	1	2
3	2	2	7433.78032 30	7389.27392 15	7625.72400 300	7082.94224 15	6993.88400 300	3	2	2
3	2	1	7440.19653 25	7396.16733 30	7632.50842 20	7088.60009 25	6998.57654 50	3	2	1
3	3	1	7504.86930 15	7462.87765 35	7694.32508 50	7185.65919 25	7101.91400 300	3	3	1
3	3	0	7505.12412 30	7463.01663 15	7694.60197 50	7185.82333 15	7101.97418 50	3	3	0
4	0	4	7452.90725 30	7406.88235 30	7645.93333 50	7077.27834 10	6983.79900 300	4	0	4
4	1	4	7454.65935 30	7409.02969 20	7647.72316 20	7082.00931 20	6989.48989 50	4	1	4
4	1	3	7505.74447 30	7459.14120 90	7698.70400 300	7139.81069 10	7046.31639 50	4	1	3
4	2	3	7524.71225 30	7480.14783 15	7717.52539 20	7176.18280 50	7086.57989 50	4	2	3
4	2	2	7540.88333 20	7496.82390 60		7190.91322 25	7101.21635 50	4	2	2
4	3	2	7599.18732 25	7557.92222 50	7789.90088 50	7282.21512 12	7198.46628 15	4	3	2
4	3	1	7600.86075 20	7558.81849 20	7791.72549 300	7283.31219 15	7198.77500 300	4	3	1
4	4	1	7693.86163 20	7654.20844 15	7881.06996 50	7417.66684 40	7339.85303 300	4	4	1
4	4	0	7693.94362 20	7654.24175 60	7881.11200 300	7417.68670 30	7339.86500 50	4	4	0
5	0	5	7552.17437 20	7505.98095 40	7745.51015 40	7178.77112 30	7085.08554 15	5	0	5
5	1	5	7552.87915 10	7506.89611 20	7746.23300 300	7181.20085 15	7088.10800 300	5	1	5
5	1	4	7625.27374 20	7578.54160 50	7818.82653 50	7264.86900 40	7170.84500 250	5	1	4
5	2	4	7636.77047 30	7591.96815 20	7830.28000 300	7291.15478 30	7200.92395 50	5	2	4
5	2	3	7666.30540 20	7623.68135 35	7863.52907 70	7324.03589 25	7230.32920 50	5	2	3
5	3	3	7716.89435 20	7677.75692 40	7909.09409 50	7402.79371 30	7315.66949 300	5	3	3
5	3	2	7722.85852 20	7680.42610 20		7406.86373 15	7321.04314 50	5	3	2
5	4	2	7812.04995 50	7772.87050 30		7538.83213 25		5	4	2
5	4	1	7812.55712 20	7773.10185 20		7538.99381 60		5	4	1
5	5	1	7930.74630 50	7894.01100 25		7704.50574 25		5	5	1
5	5	0	7930.74630 50	7894.04092 20		7704.51773 25		5	5	0
6	0	6	7668.88344 20	7622.45513 80	7863.07815 50	7297.35138 30	7203.38800 300	6	0	6
6	1	6	7669.16027 20	7622.81505 30	7863.06789 300	7298.52884 15	7204.88299 300	6	1	6
6	1	5	7762.96314 15	7716.26362 50	7957.84129 50	7409.69658 25	7315.43000 300	6	1	5
6	2	5	7768.98742 30	7723.75290 50	7963.02127 50	7426.91977 30		6	2	5
6	2	4	7824.89469 15	7774.98885 50		7480.07014 50		6	2	4
6	3	4	7856.99795 40	7811.37190 80		7546.88155 40		6	3	4
6	3	3	7872.22092 25	7829.04810 50		7557.72464 20		6	3	3
6	4	3	7953.35545 15	7915.47400 40		7684.35999 50		6	4	3
6	4	2	7955.98922 20	7916.50318 30		7685.13815 25		6	4	2
6	5	2	8072.75710 15	8036.26850 60		7849.78400 300		6	5	2
6	5	1	8072.78035 15	8036.46199 50		7850.18225 20		6	5	1
6	6	1	8213.70649 60	8180.87840 60		8042.03685 50		6	6	1
6	6	0	8213.70649 60	8180.87840 60		8042.03685 50		6	6	0
7	0	7	7803.19947 20	7756.40787 20	7995.50000 300	7433.18517 50		7	0	7
7	1	7	7803.30750 50	7756.57060 60	7997.43700 300	7433.74190 35		7	1	7
7	1	6	7917.55385 30	7870.88996 15		7572.21403 50		7	1	6
7	2	6	7920.37725 50	7874.63085 40		7582.50690 30		7	2	6
7	2	5	7999.92412 60	7948.40327 50		7660.85830 50		7	2	5
7	3	5	8021.52985 20	7974.95693 50		7713.71017 20		7	3	5
7	3	4	8048.55647 50	8004.85000 200		7736.57599 50		7	3	4
7	4	4	8121.41363 30	8081.89055 50		7854.08820 50		7	4	4
7	4	3	8125.25307 20	8085.23794 25		7856.66501 50		7	4	3
7	5	3	8238.79035 20	8202.11953 300		8020.11249 50		7	5	3
7	5	2	8238.94921 50	8202.84707 50		8020.17300 300		7	5	2
7	6	2	8379.30552 50	8347.35200 300		8212.35490 80		7	6	2
7	6	1	8379.30293 300	8347.38670 50		8212.35490 80		7	6	1
7	7	1	8540.78000 300	8513.14362 60				7	7	1
7	7	0	8540.78000 300	8513.14362 60				7	7	0

(Table continued)

Table 3. (continued)

J	K _a	K _c	(101)	(200)	(002)	(021)	(120)	J	K _a	K _c
8	0	8	7955.15989 50	7907.87822 40		7586.39892 20		8	0	8
8	1	8	7955.20404 50	7908.04018 30		7586.66474 50		8	1	8
8	1	7	8088.92947 15	8042.24036 300		7751.37027 50		8	1	7
8	2	7	8090.19265 50	8043.93187 40		7757.10502 50		8	2	7
8	2	6	8189.91623 20	8140.86303 300		7863.50937 50		8	2	6
8	3	6	8202.96815 30	8158.69893 50		7902.30785 50		8	3	6
8	3	5	8249.56797 30			7942.63637 50		8	3	5
8	4	5	8310.27383 50	8271.52541 30		8047.68813 50		8	4	5
8	4	4	8321.49858 20			8054.45817 50		8	4	4
8	5	4	8428.86150 300	8394.53400 300		8214.61000 300		8	5	4
8	5	3	8429.61525 30			8214.50100 50		8	5	3
8	6	3	8568.39010 40					8	6	3
8	6	2	8568.37470 40					8	6	2
8	7	2	8729.55224 300					8	7	2
8	7	1	8729.55224 300					8	7	1
9	0	9	8124.78149 50	8077.09165 50		7757.05807 50		9	0	9
9	1	9	8124.88156 50	8077.13827 50		7758.02695 50		9	1	9
9	1	8	8277.36173 50	8230.32749 20		7947.05773 50		9	1	8
9	2	8	8278.13852 40	8231.24200 300		7950.10211 50		9	2	8
9	2	7	8399.46036 50	8351.51403 50		8085.41056 50		9	2	7
9	3	7	8406.28203 50			8111.74933 300		9	3	7
9	3	6	8468.56694 50					9	3	6
9	4	6	8521.70748 30	8490.47173 300		8264.17763 50		9	4	6
9	4	5	8545.10834 50	8502.49580 300				9	4	5
9	5	5	8642.68374 250					9	5	5
9	5	4	8645.41875 50	8608.68065 50				9	5	4
9	6	4	8781.75061 50					9	6	4
9	6	3	8781.73393 300					9	6	3
10	0	10	8311.75485 50	8263.82640 50		7945.17350 50		10	0	10
10	1	10	8311.85795 50	8263.00500 300		7945.20050 300		10	1	10
10	1	9	8483.10662 15	8435.69200 300		8159.52549 50		10	1	9
10	2	9	8482.89922 50	8436.50289 50		8161.07112 50		10	2	9
10	2	8	8625.33655 50					10	2	8
10	3	8	8628.40661 50					10	3	8
10	3	7	8731.37315 50					10	3	7
10	4	7	8754.59949 50					10	4	7
10	4	6	8794.71355 50					10	4	6
10	5	5	8886.88999 300					10	5	5
10	6	4	9018.98733 300					10	6	4
11	0	11	8516.60035 50	8467.62216 300		8150.73899 300		11	0	11
11	1	11	8516.64549 20	8467.67700 300		8150.73816 300		11	1	11
11	1	10	8704.79108 50					11	1	10
11	2	10	8705.93153 50					11	2	10
11	2	9	8868.26161 50					11	2	9
11	3	9	8868.57947 50					11	3	9
12	0	12	8738.80600 300			8373.76377 50		12	0	12
12	1	12	8738.79900 300			8373.74000 300		12	1	12
13	0	13	8978.48558 100					13	0	13
13	1	13	8978.48558 100					13	1	13

Kitt Peak National Observatory; this same instrument was also used in the previous study by Chevillard *et al.*³ The spectra analyzed were also used in the H₂¹⁶O study,¹ and the experimental conditions are listed in Table 1. The first five runs listed in the table were of natural water vapor. The last three entries represent scans in which the gas samples consisted mainly of H₂¹⁷O and H₂¹⁸O, and, as noted in Ref. 1, the isotopic abundances of the various water-vapor isotopic species of the samples were accurately determined from comparisons with other spectra (not listed here), which have been measured in the 3500–4300 cm⁻¹ region.⁴ All spectra were recorded to cover the 3500–9000 cm⁻¹ region. Table 1 includes values of total sample pressures, temperatures, and absorption path lengths. Total-sample pressures

were measured with a Baratron gauge, and sample temperatures were inferred from readings of one or more thermistor probes that were in thermal contact with the absorption-cell walls. Two absorption cells were used: One was 2.39 cm long and was used for the oxygen-enriched sample runs; the other was a 6-m base-length multiple transversal cell with usable optical path lengths up to 433 m.

Table 2 lists the extent of the measurements obtained in each band of H₂¹⁷O and H₂¹⁸O. This listing gives the number of lines measured and the frequency range for each band and species. In all, 1807 lines of H₂¹⁷O and H₂¹⁸O were measured between 6607 and 7640 cm⁻¹. The line centers and strengths were determined with a method that was used in previous water studies.^{1,4–6} Briefly, the line

Table 4. Rotational Energy Levels of the (101), (200), (002), (021), and (120) Vibrational States of H_2^{18}O (cm^{-1}) and Uncertainties ($\text{cm}^{-1} \times 10^5$)

J	K _a	K _c	(101)	(200)	(002)	(021)	(120)	J	K _a	K _c
0	0	0	7228.87810 40	7185.87772 10	7418.72356 50	6844.59864 15	6755.51041 60	0	0	0
1	0	1	7252.02114 40	7208.88665 25	7441.97640 30	6868.18424 20	6778.89738 15	1	0	1
1	1	1	7263.44488 8	7220.74830 50	7452.98830 15	6886.30629 10	6798.20030 20	1	1	1
1	1	0	7268.72010 15	7225.98140 50	7458.32210 15	6892.23535 35	6804.04140 60	1	1	0
2	0	2	7296.81190 15	7253.50214 10	7486.93410 40	6914.08411 15	6824.49838 30	2	0	2
2	1	2	7304.10947 15	7261.52148 20	7494.16742 30	6927.62552 30	6839.14737 20	2	1	2
2	1	1	7320.59075 10	7277.17716 45	7510.14468 35	6945.34251 20	6856.64531 10	2	1	1
2	2	1	7354.32836 12	7312.21310 25	7542.95324 40	6998.78693 25	6913.46816 25	2	2	1
2	2	0	7355.77390 25	7314.26523 15	7544.47125 35	7000.01807 25	6914.56615 30	2	2	0
3	0	3	7360.92053 10	7317.48078 16	7551.21288 35	6980.11879 30	6890.26896 25	3	0	3
3	1	3	7364.75903 6	7321.89492 25	7555.04610 50	6990.26459 15	6899.87436 25	3	1	3
3	1	2	7396.69162 15	7352.87144 20	7586.63637 15	7023.98119 15	6934.62740 50	3	1	2
3	2	2	7423.32354 6	7381.16066 11	7612.74374 25	7069.47588 25	6983.69596 20	3	2	2
3	2	1	7429.84686 10	7388.12770 45	7619.61545 25	7075.22311 22	6987.54655 30	3	2	1
3	3	1	7493.68525 18	7453.94585 55	7680.74628 25	7171.31359 22	7090.63825 25	3	3	1
3	3	0	7493.94786 10	7454.10913 30	7681.03185 15	7171.48143 15	7090.73588 30	3	3	0
4	0	4	7442.69065 30	7399.13430 35	7633.18928 30	7064.25579 40	6974.20651 20	4	0	4
4	1	4	7444.39950 20	7401.19903 30	7634.92016 30	7068.90849 25	6979.74741 45	4	1	4
4	1	3	7495.58423 15	7451.47341 15	7686.05121 15	7126.76194 15	7036.72795 10	4	1	3
4	2	3	7514.20177 25	7471.97251 30	7704.44461 15	7162.65512 25	7076.30398 15	4	2	3
4	2	2	7530.67845 15	7488.85053 25		7177.80004 30	7091.08338 25	4	2	2
4	3	2	7588.00654 20	7548.83425 30	7776.25658 20	7267.82983 30	7186.88441 35	4	3	2
4	3	1	7589.72804 20	7549.89107 15	7778.12220 30	7268.95288 25	7187.41173 15	4	3	1
4	4	1	7681.66137 30	7644.16450 10	7866.57109 20	7402.12245 45	7327.21733 30	4	4	1
4	4	0	7681.74691 17	7644.19817 30		7402.14289 25	7327.23385 80	4	4	0
5	0	5	7541.74308 15	7498.00975 10	7732.55352 35	7165.54008 25	7075.26398 45	5	0	5
5	1	5	7542.42654 20	7498.88118 20	7733.24630 100	7167.90883 40	7078.18200 80	5	1	5
5	1	4	7614.90342 25	7570.67664 25	7805.93307 25	7251.65274 15	7161.08555 45	5	1	4
5	2	4	7626.13225 25	7583.67046 25	7817.05601 60	7277.50193 20	7190.47685 25	5	2	4
5	2	3	7656.49421 50	7615.72227 35	7850.57230 150	7310.85370 50	7220.22727 20	5	2	3
5	3	3	7705.69025 30	7668.19990 10	7895.37115 90	7388.35228 21	7304.05422 15	5	3	3
5	3	2	7711.81902 40	7671.55974 35	7901.93555 30	7392.51435 20	7309.72923 10	5	3	2
5	4	2	7799.85545 20	7762.75401 30	7986.58345 20	7523.23708 40	7447.44217 30	5	4	2
5	4	1	7800.38412 15	7763.00447 50	7986.96385 25	7523.40475 25	7447.56485 20	5	4	1
5	5	1	7917.26946 50	7882.52886 45		7687.51297 35	7619.78922 40	5	5	1
5	5	0	7917.27090 60	7882.56385 40		7687.51831 15	7619.79207 20	5	5	0
6	0	6	7658.20750 25	7614.22885 35	7850.06267 15	7283.88534 25	7193.28596 10	6	0	6
6	1	6	7658.47705 25	7614.57113 10	7850.03280 300	7285.02638 40	7194.72936 20	6	1	6
6	1	5	7752.29247 25	7708.09184 10	7944.88216 20	7396.22165 35	7305.40284 20	6	1	5
6	2	5	7758.14003 20	7715.26739 20	7949.57788 60	7413.07455 25	7325.32048 20	6	2	5
6	2	4	7814.51370 20	7766.95680 30	8003.26180 80	7466.51234 50	7375.58744 20	6	2	4
6	3	4	7845.50259 30	7802.18735 25	8037.33846 40	7532.35474 20	7448.20020 40	6	3	4
6	3	3	7861.31608 30	7820.31107 15		7543.42801 35	7458.91228 65	6	3	3
6	4	3	7940.92918 20	7905.26526 20	8130.68188 20	7668.71176 25		6	4	3
6	4	2	7943.87175 30	7906.38724 15	8132.40392 30	7669.51410 85		6	4	2
6	5	2	8059.29802 30	8024.70708 80	8243.79038 40	7833.07324 20	7764.31460 15	6	5	2
6	5	1	8059.32585 50	8024.92198 30	8243.85662 30	7833.13536 50	7764.34172 90	6	5	1
6	6	1	8198.70470 50	8167.66873 25		8023.37603 65		6	6	1
6	6	0	8198.70470 50	8167.66763 300		8023.37638 50		6	6	0
7	0	7	7792.25232 30	7747.89615 30		7419.45435 65	7328.99066 25	7	0	7
7	1	7	7792.35597 10	7748.05400 60	7982.45006 30	7419.99254 25	7329.08303 25	7	1	7
7	1	6	7906.52733 25	7862.33824 15	8097.32385 25	7558.39612 30	7467.56725 10	7	1	6
7	2	6	7909.25235 25	7865.88937 25	8101.23153 50	7568.40770 45	7479.96302 20	7	2	6
7	2	5	7988.01452 25	7940.16188 35	8177.43585 80	7647.12230 55	7555.27935 35	7	2	5
7	3	5	8008.98229 20	7965.78746 35	8201.27532 35	7699.05486 35	7614.26168 75	7	3	5
7	3	4	8037.79370 30	7996.22871 50	8232.29440 100	7722.36787 20	7635.85711 50	7	3	4
7	4	4	8109.06376 15	8071.52820 10	8298.49465 50	7838.37293 25	7760.28007 25	7	4	4
7	4	3	8113.25123 25	8075.18364 30	8303.96383 25	7841.03084 20	7762.23150 45	7	4	3
7	5	3	8225.34491 50	8190.40140 40	8412.26073 55	8002.63112 20		7	5	3
7	5	2	8225.52750 25	8191.22938 25	8412.61963 80	8003.04702 35		7	5	2
7	6	2	8364.30195 35	8334.03073 30		8193.65100 60		7	6	2
7	6	1	8364.29810 30	8334.06028 50		8193.65102 30		7	6	1
7	7	1	8524.00864 25	8497.85925 60				7	7	1
7	7	0	8524.00864 25	8497.85925 60				7	7	0

(Table continued)

Table 4. (continued)

J	K _a	K _c	(101)	(200)	(002)	(021)	(120)	J	K _a	K _c
8	0	8	7943.90713 10	7899.15890 35		7572.37908 15	7480.56766 40	8	0	8
8	1	8	7943.94796 20	7899.21373 15		7572.63495 30	7481.06394 80	8	1	8
8	1	7	8077.52157 20	8033.41440 80		7737.16228 15		8	1	7
8	2	7	8078.73164 15	8034.87107 40	8272.30403 40	7742.70872 60		8	2	7
8	2	6	8178.69671 20	8132.10270 70		7849.49992 50		8	2	6
8	3	6	8191.02159 20	8149.23920 100		7887.49227 15		8	3	6
8	3	5	8238.95025 50			7928.56625 30		8	3	5
8	4	5	8297.95037 15	8260.65052 25		8031.61376 20		8	4	5
8	4	4	8309.67965 50			8038.86036 25		8	4	4
8	5	4	8415.41015 40	8386.95053 30	8604.64050 50	8197.62738 40		8	5	4
8	5	3	8416.25486 20			8197.35060 45		8	5	3
8	6	3	8553.81045 60			8387.85135 50		8	6	3
8	6	2	8553.80256 60			8387.87780 30		8	6	2
8	7	2	8712.86126 300					8	7	2
8	7	1	8712.86126 300					8	7	1
9	0	9	8113.18378 20	8067.92021 20		7742.71865 30	7650.24834 45	9	0	9
9	1	9	8113.25965 50	8067.94150 70		7743.17265 80	7650.57959 50	9	1	9
9	1	8	8265.54950 60	8220.94780 50		7932.42537 30	7841.54844 20	9	1	8
9	2	8	8266.23715 25	8221.78981 55		7935.35637 50		9	2	8
9	2	7	8387.76798 25	8342.36810 55		8071.02397 25		9	2	7
9	3	7	8394.26938 20			8096.64714 30		9	3	7
9	3	6	8456.76954 25					9	3	6
9	4	6	8509.28106 20	8478.85496 70		8248.31088 40		9	4	6
9	4	5	8533.48862 30	8492.94828 35				9	4	5
9	5	5	8629.19915 25					9	5	5
9	5	4	8632.17460 150	8597.09513 50				9	5	4
9	6	4	8766.68183 40					9	6	4
9	6	3	8766.68650 50	8739.27320 60				9	6	3
10	0	10	8299.73642 10	8254.26805 60		7930.48630 50		10	0	10
10	1	10	8299.87942 20	8254.49385 40		7930.50992 50		10	1	10
10	1	9	8470.86588 25	8425.86055 80		8144.45238 40		10	1	9
10	2	9	8470.59595 20	8426.56158 20		8145.94433 60		10	2	9
10	2	8	8613.10636 15					10	2	8
10	3	8	8616.02735 25	8571.12700 50				10	3	8
10	3	7	8719.45213 25					10	3	7
10	4	7	8741.96300 100	8697.60945 160				10	4	7
10	4	6	8783.18150 55					10	4	6
10	5	5	8874.20675 50					10	5	5
10	6	4	9004.08987 30					10	6	4
11	0	11	8504.32209 30	8457.67385 60		8135.66189 300		11	0	11
11	1	11	8504.26711 30	8457.65973 100		8135.66610 300		11	1	11
11	1	10	8691.86385 50					11	1	10
11	2	10	8693.23560 30					11	2	10
11	2	9	8855.04579 25					11	2	9
11	3	9	8855.72316 30					11	3	9
12	0	12	8725.98385 100			8358.27488 50		12	0	12
12	1	12	8725.98400 100			8358.27505 300		12	1	12
13	0	13	8965.19170 200					13	0	13
13	1	13	8965.19180 100					13	1	13

centers were measured with two computer algorithms—one is LINEFINDER, and the other is based on the technique of nonlinear least squares (NLLS). The line strengths were derived from the analyses with the NLLS technique. The measured line positions obtained with both methods were slightly offset, and these results were corrected through the use of H_2^{16}O frequencies as calibration standards.¹

Energy Levels

In a recent report,⁶ the ground-state and (010) state rotational-energy levels of H_2^{17}O and H_2^{18}O and the associated estimated uncertainties were determined from microwave, far-infrared and combination-difference frequencies. The combination-difference fre-

quencies were derived from experimental transition frequencies observed in the region between 1000 and 4300 cm^{-1} . The measured line positions obtained in the present study were used along with the ground-state term values⁶ to derive values of rotational energy levels and associated estimated uncertainties in the upper vibrational states by addition of the appropriate ground-state level to each measured transition frequency of a band. These results were weighted and then averaged for each level.

Table 3 lists the term values obtained in this work for the (101), (200), (002), (021), and (120) vibrational states, along with the associated uncertainties for H_2^{17}O . A comparable listing is given in Table 4 for H_2^{18}O for these five vibrational states. Chevillard *et*

Table 5. Measured Line Positions (cm⁻¹) and Strengths (cm⁻¹/atm) at 296 K of H₂¹⁷O and H₂¹⁸O Transitions Originating from the Ground State and Observed Between 6607 and 7639 cm⁻¹^a

observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength X _a	R ^b	mot band ^c	observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength X _a	R ^b	mot band ^c	observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength X _a	R ^b	mot band ^c					
6607.966	37	3	1	4	0	4.01E-04	15	2	120	6730.858	207	7	1	7	7	1	6	4.99E-04	15	3	021				
6608.0923	-1	3	3	0	4	1.31E-04	15	2	120	6731.2379	0	4	1	3	4	2	2	3.51E-04	15	3	120				
6610.634	-70	5	1	4	6	2.35E-04	15	2	120	6732.2712	40	6	3	4	7	3	5	6.97E-04	7	3	021				
6610.9518	24	6	1	6	7	4.37E-04	10	3	120	6732.6414	-6	4	2	2	5	2	3	8.10E-03	4	0.98	2	021			
6616.760	-515	3	3	0	4	1.01E-04	10	3	120	6732.703	266	3	1	2	3	2	1	8.84E-04	15	3	120				
6619.0970	-21	4	0	4	5	2.3	4.20E-04	0.90	2	021	6733.0519	0	5	0	5	0	6	3.92E-03	4	3	021				
6619.9421	0	6	1	6	7	0	4.49E-04	10	3	120	6733.9039	-35	5	3	2	6	3	1.04E-03	6	0.87	2	021			
6621.034	90	4	1	3	5	2	5.00E-04	15	2	021	6734.602	183	7	4	4	8	4	5.45E-04	10	3	021				
6625.914	420	10	1	9	11	1	2.72E-04	15	2.16	2	021	6734.9557	-19	5	1	5	6	1.19E-02	3	3	021				
6628.349	91	2	1	2	3	1	3.02E-04	15	2	120	6736.874	5	1	0	1	1	0	1.01E-03	15	2	120				
6629.9183	55	5	0	5	6	1	6.72E-04	5	0.99	2	120	6738.818	264	2	0	2	2	1	3.73E-04	15	3	120			
6631.1600	-107	2	2	1	3	3	0	5.82E-04	10	0.89	2	120	6739.5454	0	5	2	4	6	2.5	6.92E-03	3	3	021		
6631.486	110	4	0	4	5	2	6.91E-04	15	3	021	6740.2085	-54	4	0	4	5	0	1.73E-02	5	0.99	2	021			
6632.465	-657	2	2	0	3	3	1.34E-04	15	3	021	6740.9312	-9	4	1	3	5	1	4	1.35E-02	3	3	021			
6632.635	-130	4	1	3	5	2	2.60E-04	15	3	021	6741.715	-1083	4	3	2	5	2	3	4.00E-03	15	2.99	2	120		
6632.926	-557	9	0	9	10	10	3.55E-04	15	3	021	6742.9694	-25	5	3	3	6	3	3.86E-03	3	0.99	2	120			
6633.332	-377	5	1	5	6	0	1.36E-04	15	1.39	2	120	6743.6924	-35	4	1	4	5	1	5.56E-03	5	0.96	2	021		
6633.3707	16	9	1	9	10	10	7.92E-04	10	2	021	6743.8156	133	6	4	2	7	3	2.17E-03	15	1.00	2	021			
6636.006	-122	3	1	2	4	2	5.12E-04	10	0.87	2	021	6745.1193	-48	4	2	2	5	2	3	7.88E-03	5	3	021		
6637.2279	-47	2	1	2	3	1	3.02E-04	15	3	120	6745.7420	0	6	0	6	0	2	5	7.60E-04	10	3	021			
6638.8405	-8	5	0	5	6	1	6.71E-04	10	3	120	6745.9424	0	1	0	1	1	0	8.84E-04	7	3	120				
6639.8339	-9	2	2	1	3	3	0	6.90E-04	7	3	120	6746.824	814	6	4	3	7	4	3.24E-03	15	0.82	2	021		
6644.693	-420	3	1	2	4	2	3	4.97E-04	10	3	120	6746.8770	6	5	3	2	6	3	1.30E-03	10	3	021			
6645.988	221	9	1	9	10	10	3.96E-04	15	3	021	6747.473	268	4	1	3	4	3	3.80E-04	15	1.52	2	021			
6647.0899	88	9	2	8	10	2	9	3.31E-04	0.94	2	021	6748.468	-3	2	3	5	2	4	3.26E-03	5	0.96	2	021		
6651.3000	-26	8	2	6	9	2	7	4.73E-04	0.93	2	021	6749.1780	2	3	1	2	4	3	6.12E-03	5	0.01	2	021		
6651.891	160	2	1	1	3	2	2	1.23E-04	15	2	120	6750.834	-502	6	1	5	6	3	4.36E-04	15	2	021			
6655.7011	44	4	1	4	5	0	9.08E-04	4	0.98	2	120	6752.61735	0	4	0	4	5	0	5	1.81E-02	2	3	021		
6656.1211	-19	8	0	8	9	0	9	1.84E-03	7	1.03	2	021	6752.6728	-4	4	3	2	5	2	3	3.00E-03	5	3	120	
6656.343	165	8	1	8	9	1	9	5.96E-04	10	2	021	6753.7211	-41	5	3	3	6	3	4	4.09E-03	5	3	021		
6659.301	-258	9	2	8	10	2	9	3.12E-04	15	1.09	2	021	6756.1289	-18	4	1	4	5	1	5	5.86E-03	4	3	021	
6662.3994	20	8	1	7	9	1	8	9.41E-04	10	3	021	6756.8420	-28	6	4	2	7	4	3	1.00E-03	10	3	021		
6663.417	-18	1	1	2	0	2	2	2.14E-04	15	2	120	6758.8850	22	3	1	3	4	3	8.04E-03	10	0.70	2	021		
6663.548	158	8	2	6	9	2	7	5.14E-04	10	3	120	6759.716	-246	6	4	3	7	4	3.97E-04	15	3	021			
6664.8286	-30	4	1	4	5	0	5	8.84E-04	7	3	120	6760.7628	-85	3	2	1	4	2	2	4.16E-03	10	1.02	2	021	
6666.4404	0	3	0	3	4	1	4	1.00E-03	5	2	120	6761.0542	-58	4	2	3	5	2	3	3.60E-03	8	3	021		
6666.8000	80	8	2	7	9	2	8	3.69E-04	10	1.19	2	021	6761.8024	-3	3	1	2	4	1	3	6.49E-03	5	3	021	
6666.9005	58	7	2	5	8	2	6	3.97E-04	10	0.91	2	021	6763.2245	46	4	3	1	5	3	2	5.70E-03	10	1.06	2	021
6668.2971	18	8	0	8	9	1	8	1.84E-03	3	0.21	2	021	6763.6428	-30	5	0	5	5	2	4	2.90E-04	10	3	021	
6668.528	376	8	1	8	9	1	9	6.28E-04	10	3	021	6763.7182	20	3	2	1	4	1	4	1.14E-02	5	1.00	2	120	
6670.567	140	1	0	1	2	1	7	6.95E-04	10	1.04	2	021	6765.6363	69	4	0	4	4	2	4	1.04E-03	10	0.70	2	021
6674.572	272	8	1	7	9	1	8	6.50E-04	15	3	120	6766.4361	7	3	1	3	4	4	1	1.04E-02	10	1.03	2	021	
6675.3694	48	3	0	3	4	1	4	1.16E-03	10	3	120	6767.2333	-26	4	3	2	5	3	1	1.93E-03	7	1.06	2	021	
6676.904	54	5	0	5	1	4	3	0.04E-04	15	2	120	6769.5479	-51	1	1	5	1	4	1	2.9E-03	10	0.91	2	021	
6677.948	454	4	2	3	5	1	4	1.49E-04	15	0.71	2	021	6770.8558	10	3	2	4	2	3	1.33E-02	7	2	021		
6678.5414	-60	7	0	7	8	0	8	9.86E-04	10	0.76	2	021	6771.218	77	5	4	1	6	4	2	5.68E-04	10	2	021	
6678.640	-35	3	1	3	4	0	4	3.22E-04	15	0.96	2	021	6771.3541	-24	3	0	3	4	0	4	7.74E-03	4	3	021	
6678.9010	-25	7	1	6	8	1	7	5.37E-04	10	0.84	2	021	6772.2044	33	5	4	2	6	4	3	2.30E-03	5	1.24	2	021
6678.9941	30	7	1	7	8	1	8	3.55E-03	5	0.99	2	021	6772.4597	10	2	1	3	1	2	2	3.11E-02	4	1.07	2	021
6679.0847	0	8	2	7	9	2	8	2.44E-04	10	3	021	6773.5216	0	3	2	1	4	2	2	4.21E-03	6	3	021		
6679.345	206	1	1	0	2	2	1	8.05E-04	10	3	120	6775.363	12	3	0	3	2	3	3.72E-04	15	0.92	2	021		
6679.368	566	7	2	5	8	2	6	3.97E-04	10	3	021	6776.1378	0	4	3	1	5	3	2	5.20E-03	15	0.96	2	021	
6681.128	77	4	1	4	4	2	3	3.11E-04	15	1.07	2	120	6777.7472	-24	2	0	2	3	0	3	2.68E-02	2	1.00	2	021
6682.935	468	2	0	2	3	1	3	4.01E-04	10	1.08	2	021	6777.8392	-22	4	0	4	2	3	1	4.88E-03	10	3	021	
6686.0601	62	6	2	4	7	2	5	3.01E-03	3	1.00	2	021	6778.0590	-25	3	1	3	4	1	4	2.06E-02	5	3	021	
6686.207	86	5	0	5	1	4	3	3.00E-04	15	3	120	6780.0354	-4	4	3	2	5	3	1	1.85E-03	5	3	021		
6686.4940	45	7	2	6	8	2	7	1.69E-03	10	0.88	2	021	6780.2665	0	1	1	0	1	0	1	1.12E-03	5	1.10	2	120
6690.7866	0	7	0	7	8	0	8	1.23E-03	7	3	021	6780.611	269	2	0	2	2	1	6.04E-04	15	1.09	2	021		
6691.1150	0	7	1	6	8	1	7	6.12E-04	10	3	021	6781.9326	50	6	5	1	7	5	2	5.35E-04	15	1.12	2	021	
6691.2514	35	7	1	7	8	1	8	7.77E-03	7	3	021	6782.3212	-25	5	1	5	1	4	1.54E-03	10	3	021			
6694.528	68	6	1	5	7	1	6	3.94E-03	5	0.98	2	021	6783.5032	-12	3	2	2	4	2	3	1.30E-02	10	3	021	
6697.348	-100	7	3	5	8	3	6	9.42E-04	5	0.91	2	021	6784.182	0	5	4	1	6	4	2	6.28E-04	10	3	021	
6698.695	213	6	2	4	7	2	5	2.62E-03	7	3	021	6785.127	-3	5	2	6	4	3	1	8.9E-03	10	3	021		
6698.8552	7	7	2	6	8	2	7	1.96E-0																	

Table 5. (continued)

observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength $\Sigma \epsilon$	ϵ_0	mol band ²	observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength $\Sigma \epsilon$	ϵ_0	mol band ²	observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength $\Sigma \epsilon$	ϵ_0	mol band ²					
6888.2646	37	4	3	2	3	1.65E-03	10.02	2	120	6840.6791	-87	3	2	2	4	1	1.35E-03	0.99	2	101					
6888.7565	-10	5	4	2	6	1.35E-03	10	3	200	6840.7408	8	4	0	4	3	3.44E-02	5	3	021						
6889.910	269	3	2	2	1	2.35E-04	15	2	120	6841.836	26	5	4	1	5	3.30E-04	15	2	120						
6889.0063	20	3	1	3	1	2.55E-02	4	1.01	2	021	6841.9620	-1	3	1	2	1	1.00E-02	4	3	021					
6889.024	-6	5	4	1	6	5	3.90E-03	10	3	200	6843.8033	7	4	1	4	5	3.30E-04	15	0.81	2	101				
6889.3867	-15	3	3	0	3	1	7.90E-03	3	0.97	2	021	6844.0194	27	9	4	6	10	4	7	1.09E-03	10	3	101		
6889.6613	4	4	3	1	4	2	1.16E-02	6	1.02	2	021	6844.0416	29	4	3	2	5	1	5.75E-03	10	2	200			
6890.3292	-1	2	0	2	1	0	1.31E-02	5	2	021	6844.0805	23	5	5	4	1	2.81E-02	6	2	021					
6890.5384	0	3	0	3	0	2	1	8.70E-04	10	3	120	6844.306	-7	5	0	5	4	0	9.06E-03	0.98	2	021			
6890.8772	33	2	1	2	1	1	7.65E-03	4	2	021	6844.484	-259	9	4	6	10	3	7	5.60E-04	15	1.49	2	200		
6891.4744	10	4	2	2	4	2	3	4.45E-03	4	3	021	6844.6215	-44	7	2	5	8	3	6	1.54E-03	10	3	200		
6891.919	92	5	3	2	5	3	1.58E-03	10	2	021	6845.3467	-15	4	3	1	5	4	2	2.58E-03	3	0.99	2	200		
6895.0296	-54	3	1	2	3	1	1.85E-03	10	3	021	6846.406	138	3	2	2	3	0	3	1.69E-03	10	3	021			
6895.6198	48	3	3	3	3	2	5.23E-03	6	3	021	6847.174	-24	3	2	1	4	4	0	6.50E-04	15	2	101			
6896.6849	-61	5	2	3	5	2	4	9.00E-04	15	0.95	2	021	6847.643	35	8	5	9	5	4	1.08E-03	4	1.00	2	101	
6897.045	109	5	1	5	6	3	4	7.00E-04	15	1.07	2	101	6847.926	29	4	1	4	3	2	1.60E-04	15	0.53	2	120	
6898.0458	42	6	3	3	6	3	4	1.80E-03	4	0.99	2	021	6848.5716	31	3	2	2	4	1	1.29E-03	10	3	101		
6898.4150	-17	6	3	3	7	4	4	6.80E-04	10	0.91	2	200	6848.7971	13	3	2	2	2	1	1.64E-02	10	3	021		
6899.0274	4	4	3	2	4	2	3	2.50E-03	10	3	120	6849.391	-78	8	5	4	9	5	5	3.57E-04	1.00	2	101		
6900.0396	-7	4	3	2	4	3	1.94E-02	4	3	021	6950.5243	-52	4	3	2	5	4	1	6.85E-03	5	3	200			
*6900.514	-480	13	13	13	13	1	1.00E-02	1.66	3	021	6950.876	58	6	1	5	6	1	6	6.40E-04	15	0.99	2	021		
6901.8912	23	3	1	3	1	3	0	2.58E-02	4	3	021	6950.980	-198	8	5	3	7	5	2	1.00E-03	10	2	021		
6902.0806	56	9	2	7	10	3	8	3.75E-04	7	1.24	2	200	6951.4295	164	7	4	3	5	2	1.00E-03	10	2	021		
6902.2617	3	3	3	0	3	3	1	8.76E-03	10	3	021	6951.4592	0	4	3	1	5	4	2	6.33E-03	7	3	200		
6902.5064	14	4	3	1	4	3	2	1.18E-02	5	3	021	6951.8079	-6	10	2	9	11	2	10	2.53E-04	15	0.64	2	101	
6903.91	-238	4	1	3	4	4	3	3.56E-03	15	2	021	6952.0571	38	7	5	2	7	5	3	3.27E-04	10	1.04	2	021	
6903.0587	16	2	0	2	1	0	1	3.18E-02	4	3	021	6952.323	-30	10	1	9	11	1	10	1.96E-03	10	1.13	2	021	
6903.3192	12	2	1	1	1	1	0	1.03E-02	2	1.00	2	021	6952.9598	-61	6	5	2	6	5	1	8.85E-04	15	2	021	
6903.421	23	5	3	3	4	2	1	7.95E-03	10	0.97	2	120	6953.050	0	6	5	5	2	1	2.57E-03	15	2	021		
6903.6225	-7	2	1	2	1	1	1	7.43E-03	3	3	021	6953.043	11	12	1	12	1	12	1	1.00E-03	15	2	021		
6904.3061	-59	5	2	3	6	4	2	1.20E-03	10	1.05	2	101	6953.120	3	11	0	11	12	0	12	6.85E-04	15	2	021	
6904.686	195	5	2	3	5	3	3	1.47E-03	10	3	021	6953.1687	-21	3	2	1	2	0	5.50E-03	6	3	021			
6905.8076	65	5	1	5	6	3	4	7.65E-04	10	3	101	6953.456	82	5	2	4	5	0	5	1.12E-03	10	1.08	2	021	
6908.0192	20	10	2	9	11	10	1	1.60E-04	15	0.64	2	200	*6953.8309	103	5	1	5	0	5	0	8.45E-03	10	2	021	
6908.5586	50	3	2	1	2	1	2	2.11E-02	3	0.98	2	120	6953.890	-3	4	1	3	3	1	2	2.58E-02	4	2	021	
6908.9076	-27	5	2	3	5	2	1	1.01E-02	10	1.04	2	101	6953.980	-132	9	3	7	10	3	8	1.78E-03	10	2	101	
6909.6577	15	2	3	5	4	2	1	3.89E-04	10	2	101	6954.109	-6	2	4	7	3	5	2	1.00E-03	15	2	021		
6910.1909	-45	3	3	3	0	2	0	2	1.16E-02	10	2	021	6954.479	-138	8	4	9	5	2	1.14E-03	10	2	021		
6910.4814	0	4	4	1	5	0	5	0	5.78E-03	10	2	200	6954.560	-199	4	2	3	4	0	4	3.50E-04	15	3	021	
6910.521	222	4	4	0	5	1	1	1.72E-03	10	2	200	6954.739	1	9	2	7	2	8	7.39E-04	15	0.94	2	101		
6910.654	156	6	3	3	6	4	2	2.00E-03	10	3	021	6954.958	-169	3	2	1	4	0	4	6.46E-04	10	3	101		
6911.091	122	10	3	7	11	3	8	3.92E-04	15	0.93	2	101	6956.0416	115	4	1	4	5	2	3	2.65E-03	10	0.97	2	200
6911.2759	-4	3	1	3	2	1	2	1.01E-02	10	1.04	2	021	6956.293	-32	5	1	4	6	3	3	5.04E-04	15	2	101	
6911.495	141	5	3	3	4	4	2	9.75E-04	10	3	101	6956.8677	15	5	1	4	4	1	4	2.87E-02	4	3	021		
6912.6722	-90	7	4	4	7	4	3	7.94E-04	10	2	021	6956.9307	44	8	5	3	9	5	4	7.85E-04	10	3	101		
6912.7426	-33	6	1	5	7	3	4	6.07E-04	10	2	101	6957.1506	29	5	0	5	4	0	4	9.85E-03	4	3	021		
6913.4698	0	4	2	3	3	1	2	7.54E-04	10	3	120	6957.780	97	7	3	5	7	5	2	4.06E-04	15	2	101		
6915.5064	-6	4	1	3	4	1	4	2.35E-03	10	3	021	6957.8996	39	4	2	3	2	2	6.20E-03	3	2	021			
6916.0524	12	2	1	1	1	1	0	2.24E-02	4	3	021	6958.1180	10	9	0	9	10	1	10	1.81E-03	15	2	200		
6916.062	51	6	2	4	6	2	5	1.15E-03	15	2	021	6958.157	258	9	1	9	10	10	10	6.39E-04	15	2	200		
6916.525	76	6	4	3	6	4	2	7.97E-04	15	2	021	6959.0471	0	4	4	1	3	2	3.71E-04	15	1.03	2	101		
6916.5842	-9	4	1	5	5	0	5	5.50E-03	7	3	200	6959.154	142	8	3	5	9	3	6	3.09E-03	10	2	021		
6916.6212	6	4	4	0	5	1	1	7.90E-03	10	3	021	6959.8104	-24	6	1	6	5	1	5	7.08E-03	8	2	021		
6918.4437	-44	5	4	2	5	4	1	6.05E-03	4	2	021	6959.8399	31	6	0	6	5	0	5	2.11E-02	15	2	021		
6918.4831	201	6	4	2	6	4	3	3.20E-03	10	2	021	6960.108	1	8	2	7	9	1	8	1.79E-03	15	1.16	2	101	
6918.861	47	5	4	1	5	4	2	2.04E-03	6	1.01	2	021	6960.3781	0	6	2	4	7	3	5	1.37E-03	10	3	101	
6919.3492	0	3	2	1	2	1	2	9.05E-03	4	3	120	6961.115	-198	10	2	9	11	10	10	6.35E-04	15	3	021		
6919.4497	-13	4	4	1	4	4	0	4.85E-03	3	2	021	6961.5890	-7	10	1	9	11	1	10	1.63E-03	15	3	101		
6919.4990	-32	4	4	0	4	1	1	1.51E-02	4	2	021	6962.2657	0	11	0	11	12	0	12	6.00E-04	10	3	101		
6919.662	311	9	5	10	6	3	4	3.42E-04	15	2	101	6962.3080	19	11	1	12	12	1	12	1.54E-03	10	3	101		
6920.5273	57	5	3	2	6	3	4	4.55E-03	10	0.97	2	200	6963.236	-25	4	1	4	5	2	3	3.00E-03	10	3	200	
6920.710	388	10	3	7	11	3	8	3.10E-04	15	3	101	6963.240	-96	9	3	7	10	8	1	1.95E-03	10	3	021		
6921.832	-305	9	4	5	10	4	6	2.93E-04	15	2	101	6963.451	-62	6	1	5	6	1	6	4.15E-04	10	3	021		
6922.101	273	6	1	5	7	3	4	6.40E-04	10	3	101	6963.668	-302	8	4	5	9	4	6	1.53E-03	15	1.87	2	101	
6922.9709	42	3	3	3	2	0	2	1.31E																	

Table 5. (continued)

observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength X_a	R^B	mol band ^a	observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength X_a	R^B	mol band ^a	observed position	o-c	upper $K_a K_c$	lower $K_a K_c$	observed strength X_a	R^B	mol band ^a
*7014.226	-251	10 0 10	9 0 9	3.17E-03	10	2 021	7050.5980	-14	6 1 5	7 1 6	5.55E-02	3	2 101	7082.7245	0	10 1 9	9 1 8	9.02E-04	10	3 021
7014.5110	14	3 1 3	4 2 2	2.74E-03	10	3 200	7050.7225	30	2 1 2	3 2 1	1.57E-02	2	2 200	7083.0508	0	10 2 9	9 2 8	2.95E-04	10	3 021
7014.6595	0	9 0 9	8 0 8	1.34E-03	7	3 021	7051.1549	56	6 4 3	6 4 3	2.40E-03	10	0.97	7083.0738	-39	5 2 4	5 2 3	2.52E-03	7	1.27 2 200
7015.3616	20	3 2 1	4 3 2	1.62E-02	3	3 200	7051.339	-97	7 0 7	8 0 8	1.81E-02	5	2 101	7083.2768	-11	5 1 4	6 1 5	3.66E-02	2	3 101
7015.5361	0	9 1 9	8 1 8	2.32E-03	10	3 021	7051.357	-23	7 1 7	8 1 8	5.52E-02	5	2 101	7083.358	-104	7 5 2	8 4 5	6.62E-04	10	3 200
7015.994	490	3 1 2	4 3 1	2.25E-04	15	2 101	7051.5434	120	6 2 5	7 2 6	1.81E-02	10	2 101	7083.9427	15	6 0 6	7 0 7	9.00E-02	3	3 101
7017.2155	-45	7 1 6	6 1 7	2.86E-03	10	0.95	7051.948	-199	5 2 3	5 4 2	1.47E-03	15	2 101	7083.9993	10	4 1 3	5 3 2	6.70E-02	6	2 101
7017.502	242	8 1 8	8 2 7	8.40E-04	15	1.14	7052.6038	28	5 0 5	6 1 6	2.46E-02	3	0.98	7084.3687	0	4 1 4	5 0 5	3.20E-02	4	3 200
7017.5250	-5	6 5 1	7 5 2	4.55E-03	3	3 101	7052.9304	-10	9 1 8	8 1 7	7.68E-04	15	1.17	7084.715	201	5 1 5	5 2 4	2.65E-03	10	2 200
7017.7030	1	6 5 2	7 5 3	1.73E-03	5	3 101	7053.127	-61	7 2 6	7 3 5	6.95E-04	15	2 021	7085.148	-14	8 1 7	8 3 6	1.29E-03	15	3 101
7017.7486	8	7 3 5	8 3 6	6.55E-03	6	3 101	7053.194	-198	8 1 7	8 2 6	3.47E-04	15	2 200	7085.1608	-29	3 2 4	6 2 5	8.40E-02	6	3 101
7017.958	115	7 2 6	6 2 5	7.10E-03	15	2 021	7053.2084	-52	5 3 2	6 3 3	1.54E-02	6	2 101	7085.5198	-7	4 2 2	5 2 3	1.10E-01	4	2 101
7018.1724	48	6 4 2	7 4 3	1.21E-02	4	1.01	7053.442	-22	9 2 8	8 2 7	1.88E-03	15	0.96	7085.6540	-49	7 0 7	7 2 6	1.39E-03	10	2 101
7018.4276	-56	7 2 5	8 2 6	3.02E-03	10	3 101	7053.5226	70	7 0 7	7 1 6	1.99E-03	6	3 021	7085.9648	-38	1 1 1	2 2 0	8.15E-03	10	2 200
7019.0333	2	6 4 3	7 4 4	2.43E-03	6	2 101	7053.6231	0	5 4 2	4 4 1	3.33E-03	6	3 021	7086.0126	-2	2 0 2	3 2 1	8.61E-03	10	2 101
7020.2253	-49	5 1 4	6 2 5	1.13E-02	3	2 200	7053.6729	67	7 3 5	6 3 4	4.53E-03	10	2 021	7086.5463	8	4 4 0	5 4 1	2.22E-02	4	3 101
7020.8677	77	6 2 5	7 1 6	4.08E-03	10	5 200	7053.758	103	5 4 1	4 4 1	1.90E-03	5	3 021	7086.7024	6	4 4 1	5 4 2	7.30E-03	3	3 101
7021.340	69	5 2 4	5 4 1	8.40E-04	15	2 101	7054.036	105	5 1 5	6 0 6	8.58E-03	7	2 200	7087.3400	8	7 4 4	6 4 3	2.46E-03	10	2 021
7021.3533	-46	6 2 4	5 2 3	1.02E-02	4	1.00	7054.252	74	3 1 2	4 2 3	2.03E-02	10	2 200	7087.4105	23	4 3 2	5 3 3	2.10E-02	5	2 101
7021.743	851	6 3 3	7 2 5	3.98E-03	15	2 200	7054.369	-640	4 2 2	3 0 3	4.80E-04	15	2 021	7087.6971	0	8 3 6	7 3 5	5.10E-04	15	3 021
7021.7670	46	6 3 4	7 3 2	2.03E-02	5	2 101	7054.901	94	5 1 4	6 4 3	5.08E-04	15	0.67	7087.7191	-2	9 1 9	8 4 2	1.89E-03	10	2 200
7021.9877	-8	5 3 3	4 3 2	8.98E-03	4	3 021	7055.2564	5	5 2 3	6 2 4	1.48E-02	5	1.01	7088.843	-32	7 4 3	6 4 2	7.95E-04	15	2 021
7022.016	111	2 1 2	3 1 3	9.83E-04	15	2 101	7055.673	-130	4 2 2	4 1 1	1.20E-03	10	3 101	7089.0167	-1	8 3 5	7 3 4	1.70E-03	10	2 021
7022.9658	-46	6 1 5	7 4 4	1.78E-03	15	2 002	7055.8799	-4	3 0 3	4 2 2	2.55E-03	10	3 101	7089.5136	91	7 1 6	7 2 5	2.48E-03	6	3 200
7024.200	45	7 4 4	8 3 5	7.80E-04	15	1.12	7057.667	20	6 3 4	6 4 3	2.38E-03	10	3 200	7089.7880	-47	5 2 4	5 3 3	1.79E-03	10	3 200
7024.3887	43	8 1 8	8 2 7	9.15E-04	10	3 200	7057.6990	-96	2 1 2	3 2 1	1.69E-02	10	3 200	7090.663	136	7 1 7	7 1 6	3.80E-03	10	0.89 2 101
7024.6877	-4	5 3 2	4 3 1	2.75E-03	5	3 021	7057.746	69	5 4 1	6 4 2	5.97E-03	5	3 101	7091.0920	-7	3 1 3	3 3 0	1.46E-03	10	3 101
*7025.864	1	11 1 11	10 1 10	1.58E-03	10	2 021	7058.3456	75	5 4 2	6 4 3	1.89E-02	5	3 101	7091.7683	21	5 1 5	5 2 4	2.47E-03	7	3 200
7026.9317	-52	5 1 4	6 2 5	1.18E-02	7	3 200	7058.8975	0	7 2 5	6 2 4	1.70E-03	15	3 021	7092.502	-360	1 1 0	2 2 1	3.22E-02	10	2 200
7027.0324	-6	7 1 6	8 1 7	9.05E-03	3	1.03	7059.150	389	5 2 3	5 4 2	7.12E-04	15	3 101	7092.6806	-29	4 2 3	4 3 2	8.13E-03	4	2 200
7027.060	0	10 1 10	9 1 9	6.75E-04	5	3 021	7059.7364	41	5 0 5	6 1 6	2.43E-02	3	3 200	7092.8709	45	1 1 2	2 0 3	8.18E-03	3	2 200
7027.0715	0	10 1 10	9 1 9	1.96E-03	5	3 021	7060.0201	0	7 2 6	7 1 5	1.09E-03	15	3 200	7093.626	52	6 4 2	7 3 3	7.45E-04	15	2 200
7027.3383	10	2 6 8	3 5 7	2.44E-02	4	0.98	7060.0771	-7	6 1 5	7 1 6	5.50E-02	4	3 101	7093.6524	18	3 0 3	4 1 4	4.22E-02	3	2 200
*7027.6511	176	8 0 8	9 0 9	3.35E-02	3	2 101	7060.3082	58	5 3 3	6 3 4	4.48E-02	3	2 101	7093.6861	-26	4 3 1	5 3 2	6.62E-02	3	3 101
7027.6938	45	6 4 2	7 4 3	1.20E-02	5	3 101	7060.8009	0	7 0 7	8 0 8	1.73E-02	4	3 101	7093.763	-257	7 1 6	7 3 5	8.85E-04	10	2 101
7028.715	108	6 4 3	7 4 4	2.76E-03	10	3 101	7060.8157	-95	7 1 7	8 1 8	5.18E-02	4	3 101	7094.941	-28	9 3 7	8 3 6	1.07E-03	10	2 021
7029.319	-237	5 4 1	5 5 0	4.65E-04	15	1.35	7060.9714	34	6 2 5	7 2 6	1.75E-02	3	3 101	7095.0899	1	4 2 2	5 2 3	1.02E-01	3	3 101
7029.374	93	5 2 4	5 4 1	8.40E-04	15	3 101	7061.0066	-33	3 1 2	4 2 3	2.13E-02	4	3 200	7095.1830	-11	7 0 7	7 2 6	1.55E-03	10	3 101
7029.9057	-31	2 1 2	3 1 3	2.68E-02	2	1.03	7061.1767	-19	5 1 5	6 0 6	8.00E-03	10	3 200	7095.2907	15	2 0 2	3 2 1	8.70E-03	10	3 101
7029.9598	-83	6 3 4	7 2 5	3.03E-03	10	3 200	7061.9931	12	8 0 8	8 2 7	1.80E-03	6	2 101	7096.8970	15	6 4 2	7 3 3	7.45E-04	15	3 101
7030.218	80	7 1 6	6 1 7	5.20E-03	10	3 021	7062.068	752	8 2 6	8 4 5	4.95E-04	15	2 101	7097.0079	26	4 3 2	5 3 3	2.20E-02	4	3 101
7030.262	-32	6 0 6	7 1 7	3.35E-02	3	1.03	7062.8717	17	5 3 2	6 3 3	1.53E-02	4	3 101	7097.0807	39	5 1 5	6 1 6	1.57E-01	3	2 101
7030.5027	-25	2 2 2	3 0 1	1.34E-03	15	5 101	7063.697	2	4 1 4	4 1 3	5.00E-04	15	2 101	7097.2235	-21	4 1 3	5 1 4	1.86E-01	4	2 101
7030.7934	7	6 1 6	7 0 7	1.52E-02	3	1.01	7063.755	-277	7 3 4	6 3 3	2.29E-03	15	2 021	7098.506	-326	8 2 7	8 2 6	4.65E-04	10	2 101
7030.8973	-22	7 2 6	6 2 5	7.70E-03	10	3 021	7064.119	-128	6 1 6	6 2 5	3.60E-03	10	2 200	7098.996	-925	6 2 7	7 4 3	1.65E-03	15	2 200
7031.3559	-15	6 3 3	7 3 2	2.22E-02	3	3 101	7064.163	-454	6 4 3	5 4 2	9.40E-04	10	2 021	7099.0660	-8	3 2 2	3 3 1	2.53E-03	10	2 200
7031.391	-521	6 4 3	6 5 2	2.43E-04	15	3 200	7064.3446	0	5 2 3	6 2 4	1.28E-02	2	3 101	7099.3419	0	4 2 3	4 3 2	8.05E-03	10	3 200
7031.7583	-17	6 3 4	7 3 3	2.70E-03	10	1.07	7064.451	-209	8 1 8	8 1 7	5.55E-04	15	0.86	7099.3939	-304	1 1 0	2 2 1	3.06E-02	7	3 200
7032.1707	5	2 2 0	3 3 1	6.65E-03	4	0.94	7064.721	-16	6 4 2	5 4 1	2.81E-03	10	0.85	7099.4519	-36	5 1 5	5 0 4	1.50E-03	7	2 021
7032.604	103	8 3 6	8 4 5	5.45E-04	10	2 200	7065.125	357	5 1 4	6 4 3	5.46E-04	10	3 002	7099.6493	7	5 0 5	5 1 4	9.25E-03	10	2 200
7032.7402	-63	6 4 3	7 3 5	6.60E-03	4	0.99	7065.7157	-2	6 4 3	7 3 4	2.56E-03	10	2 200	7100.0332	-38	4 2 3	5 2 4	4.30E-02	2	2 101
7033.1654	-121	8 2 7	8 3 6	8.55E-04	10	1.07	7065.9887	0	9 1 8	8 1 7	5.05E-04	15	2 021	7100.3831	0	7 4 4	6 4 3	2.50E-03	10	3 021
7033.230	3024	6 1 5	7 4 4	7.75E-04	15	3 002	7066.189	-168	6 3 3	7 4 1	1.90E-03	15	2 200	7100.4218	27	7 1 7	7 1 6	4.05E-03	10	3 101
7033.231	-241	7 4 4	8 3 5	7.75E-04	10	3 200	7066.4502	0	9 2 8	8 2 7	2.00E-03	10	3 021	7100.611	-134	7 2 5	7 3 4	1.82E-03	10	2 200
7034.0610	16	6 2 4	7 2 5	3.55E-02	4	3 021	7066.6378	-17	7 3 5	6 3 4	4.10E-03	6	3 021	7100.6605	-41	3 1 3	4 0 4	1.35E-02	4	2 200
7034.2767	0	6 2 4	5 2 3	9.20E-03	6	3 021	7066.768	120	5 3 2	5 4 1	1.64E-03	10	0.98	7100.7391	45					

Table 5. (continued)

observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	
7117.1389	-11	3 1 3	3 2 2	4.02E-03	15	2 200	7160.47496	-27	2 0 2	3 0 3	3.60E-01	2	2 101	7211.37798	-18	3 3 1	3 3 0	3.03E-01	3	2 101	
7117.235	-302	1 0 1	2 1 2	1.16E-03	15	2 101	7160.586	-94	9 5 5	9 5 4	9.15E-04	5	2 101	7211.430	87	5 1 4	5 4 1	2.27E-03	10	3 002	
7117.274	-6	6 1 6	6 2 5	8.40E-03	10	3 101	7162.5415	-17	2 1 2	3 1 3	1.02E-01	2	2 101	7211.8533	2	3 3 0	3 3 1	1.03E-01	2	2 101	
7117.297	12	6 1 6	6 1 5	2.70E-03	10	2 101	7163.209	-9	8 6 3	8 6 2	5.35E-04	7	3 101	7212.52432	6	3 2 2	3 2 1	1.78E-01	2	2 101	
7117.621	-84	5 4 1	6 3 4	2.80E-03	10	2 200	7163.227	41	8 6 2	8 6 3	1.59E-03	7	3 101	7213.049	8	6 0 6	5 2 3	9.00E-04	15	2 101	
7118.64396	6	4 0 4	5 0 5	2.48E-01	2	2 101	7163.3365	40	2 0 2	2 2 1	1.05E-02	6	1.00	7213.278	86	4 1 3	3 3 0	9.50E-04	15	2 101	
7119.0383	-6	2 0 2	3 1 3	1.45E-02	5	3 200	7163.5776	-11	3 3 0	4 2 3	6.90E-03	5	3 200	7214.0476	28	4 2 2	4 1 3	1.24E-02	4	1.07	2 200
7119.1836	-16	4 1 4	5 1 5	7.70E-02	5	2 101	7163.632	-279	4 2 2	5 1 5	1.13E-03	5	3 200	7214.7129	62	2 1 1	2 0 2	2.61E-02	3	3 200	
7121.034	226	6 3 7	7 2 6	6.70E-04	10	3 200	7164.1518	17	9 4 6	9 4 5	7.40E-04	10	3 101	7214.9405	0	0 0 0	1 0 1	2.25E-01	3	3 101	
7121.1090	11	5 3 2	6 2 5	5.10E-03	10	1.07	7164.299	-14	3 2 1	4 1 4	9.05E-03	10	2 200	7215.2451	31	3 2 1	3 1 2	4.46E-02	4	2 200	
7121.195	-309	7 3 4	8 2 7	4.30E-04	10	3 101	7165.4766	-1	3 0 3	3 2 2	6.60E-03	3	3 101	7215.776	15	7 3 4	7 2 5	5.00E-03	15	2 200	
7121.8885	9	3 1 2	4 1 3	8.70E-02	5	2 101	7165.5106	6	6 6 0	6 6 1	2.18E-02	5	2 101	7215.8095	192	2 0 2	3 1 3	3.35E-04	15	3 002	
7122.554	-76	7 5 3	6 5 2	1.00E-03	15	2 021	7165.9703	7	2 0 2	2 1 1	1.39E-02	5	3 200	7215.934	55	6 3 3	6 3 4	1.80E-02	10	1.02	2 101
7122.9484	27	3 3 0	4 3 1	2.22E-02	3	3 101	7166.8643	108	1 0 1	1 1 0	3.68E-02	3	2 200	7216.4574	53	5 2 3	6 3 4	4.64E-04	15	3 002	
7123.0466	0	8 4 5	7 4 4	2.97E-04	15	3 021	7166.980	-59	6 1 6	5 3 3	1.15E-04	15	3 101	7216.5349	13	3 1 2	3 0 3	3.68E-02	3	2 200	
7123.0939	-16	5 1 4	5 3 3	2.11E-03	10	3 101	7167.0264	-22	6 2 5	6 2 4	3.60E-03	10	3 101	7216.7534	-9	2 0 2	1 1 1	5.47E-03	6	1.00	2 200
7123.162	-286	3 1 2	3 3 1	2.31E-04	15	3 101	7168.206	201	8 5 4	8 5 3	6.95E-04	10	2 101	7217.0111	-23	4 3 2	4 3 1	4.70E-02	2	3 101	
7124.0634	3	3 3 1	4 3 2	6.75E-02	3	3 101	7169.4327	-5	7 3 5	7 3 4	5.55E-03	7	2 101	7217.3621	35	5 2 3	5 1 4	1.90E-02	5	0.88	2 200
7124.1075	-3	3 1 3	3 2 2	5.15E-03	10	3 021	7169.4871	0	7 6 2	7 6 1	7.30E-03	4	3 101	7217.500	271	6 2 4	5 4 1	3.91E-04	15	3 101	
7124.3111	1	4 0 4	4 1 3	5.22E-03	10	2 200	7169.5980	-29	4 1 4	4 1 3	9.24E-03	4	0.94	7217.073	-91	6 3 3	6 2 4	4.00E-03	15	2 200	
7124.70326	-10	3 2 2	4 3 3	1.62E-01	2	2 101	7169.886	-21	8 5 3	8 5 4	2.52E-03	10	2 101	7217.0942	13	2 1 2	2 1 1	3.77E-02	3	3 101	
7124.9388	26	4 1 3	4 3 2	4.15E-03	10	3 101	7169.996	-275	9 5 5	9 5 4	7.70E-04	10	3 101	7217.398	236	3 1 2	2 2 1	3.44E-03	15	2 101	
7125.019	542	9 3 7	9 3 6	6.10E-04	10	3 101	7170.1880	-71	2 0 2	3 0 3	3.66E-01	3	3 101	7217.437	-23	2 2 0	3 0 3	8.05E-04	15	2 101	
7125.116	-4	3 2 1	4 2 2	5.30E-02	2	3 101	7170.376	-4	5 2 3	6 1 6	1.20E-03	15	2 200	7217.4767	12	2 2 0	2 1 1	1.16E-02	10	2 200	
7125.1846	-21	2 1 2	3 0 3	2.92E-02	2	2 200	7170.946	233	4 2 2	5 1 5	1.18E-03	10	3 200	7217.5452	-4	2 2 1	2 2 0	1.37E-01	2	3 101	
7125.5178	-26	5 1 4	5 2 3	1.31E-02	3	0.97	7171.512	79	8 4 5	8 4 4	9.53E-04	15	2 101	7217.0550	18	4 3 1	4 3 2	1.29E-01	3	3 101	
7126.028	-165	5 4 1	6 3 4	4.15E-03	15	3 200	7171.8630	-10	3 2 1	4 1 4	1.10E-02	5	3 200	7217.6788	-4	5 3 2	5 3 3	1.85E-02	3	3 101	
7126.1623	0	8 4 4	7 4 3	1.15E-03	10	3 021	7172.1622	0	2 1 2	3 1 3	9.95E-02	3	3 101	7217.748	-30	1 1 1	0 0 0	1.16E-02	15	2 200	
7126.445	188	1 0 1	2 2 0	1.70E-03	10	3 101	7172.5810	-6	2 0 2	2 2 1	1.04E-02	4	3 101	7217.1015	-4	3 3 1	3 3 0	3.12E-01	3	3 101	
7127.1534	16	6 1 6	6 1 5	3.00E-03	10	3 101	7172.697	-17	2 0 3	3 1 3	1.05E-02	10	2 200	7217.42158	13	1 1 1	1 1 0	2.92E-01	4	2 101	
7127.5743	-59	5 0 5	5 2 4	4.80E-03	7	0.99	7173.590	-49	7 6 2	6 6 1	4.40E-04	10	3 021	7217.5622	-26	3 3 0	3 3 1	1.05E-01	5	3 101	
7128.0462	52	2 1 2	2 2 1	1.18E-02	3	2 200	7173.9316	15	1 0 1	2 1 1	7.98E-02	2	3 200	7217.6933	-5	4 2 2	4 1 3	3.12E-02	7	3 200	
7128.2462	-6	4 0 4	5 0 5	2.38E-01	3	3 101	7174.0831	15	1 0 1	1 1 0	3.87E-02	5	3 200	7217.9764	-31	4 1 3	3 3 0	9.54E-04	10	3 101	
7128.7792	8	4 1 4	5 1 5	8.10E-02	3	3 101	7174.142	35	7 5 3	7 5 2	8.00E-03	15	2 101	7222.2981	0	2 2 0	2 2 1	3.95E-01	4	2 101	
7128.801	151	7 2 6	7 2 5	4.98E-03	10	3 101	7174.5375	30	7 5 2	7 5 3	2.73E-03	10	0.96	7222.34454	0	3 2 2	3 2 1	1.85E-01	3	3 101	
7128.816	-72	5 3 2	6 2 5	5.60E-03	10	3 200	7174.9411	0	6 6 0	6 6 1	2.04E-02	4	3 101	7223.0575	26	3 2 1	3 1 2	5.04E-02	3	3 200	
7129.8980	0	1 0 1	2 1 2	3.80E-02	4	2 200	7177.435	-139	5 2 3	6 1 6	1.20E-03	15	3 200	7223.090	0	6 0 6	5 2 3	2.90E-03	15	3 101	
7131.531	16	5 0 6	6 3 4	5.47E-04	15	2 200	7177.572	165	8 5 4	8 5 3	8.45E-04	10	3 101	7223.473	27	7 2 1	7 1 0	5.90E-03	3	3 101	
7131.5959	-7	3 1 2	4 1 3	8.55E-02	4	3 101	7179.1164	-16	8 5 3	8 5 4	2.50E-03	10	3 101	7223.9081	-13	3 1 2	3 0 3	3.60E-02	3	3 200	
7131.682	735	9 4 6	8 4 5	7.67E-04	15	2 021	7179.1832	-19	6 5 2	6 5 1	8.53E-03	3	2 101	7224.0097	4	2 0 2	1 1 1	5.76E-03	10	3 200	
7131.7520	20	4 0 4	4 1 3	5.77E-03	5	3 200	7179.2493	-19	6 5 1	6 5 2	2.10E-02	5	2 101	7224.8021	15	5 2 3	5 1 4	2.28E-02	4	3 200	
7132.5880	-12	2 1 2	3 0 3	3.00E-02	4	3 200	7179.5285	-30	4 1 4	4 1 3	1.01E-02	4	3 101	7225.031	-94	7 3 4	7 3 5	1.50E-03	15	2 101	
7132.7478	-36	5 1 4	5 2 3	1.34E-02	4	3 200	7180.4892	-23	2 0 3	3 1 3	1.00E-02	5	3 200	7225.0906	-35	3 2 1	3 2 2	5.75E-02	3	2 101	
7134.3412	-20	2 2 2	4 2 3	1.58E-01	2	3 101	7180.665	2	7 3 5	7 3 4	3.07E-03	6	3 101	7225.1488	8	6 3 3	6 3 4	1.82E-02	5	3 101	
7134.9808	33	2 1 2	2 2 1	1.21E-02	10	3 200	7180.9740	33	5 2 4	5 2 3	2.92E-02	3	2 101	7225.775	-163	6 2 4	6 1 5	3.77E-03	15	2 200	
7135.724	112	4 3 1	5 2 4	2.81E-03	10	1.06	7181.333	-269	8 4 5	8 4 4	9.40E-04	10	2 101	7226.133	-443	3 0 3	2 2 0	1.08E-03	15	2 101	
7136.0847	6	3 1 2	4 2 3	5.77E-04	15	3 021	7182.0937	0	1 1 2	2 0 2	1.14E-01	2	2 101	7226.3019	92	3 1 2	2 2 1	1.11E-03	7	3 101	
7137.0140	5	4 1 3	4 2 2	7.53E-03	10	2 200	7183.3633	-63	7 4 4	7 4 3	8.55E-03	4	2 101	7226.4015	34	5 3 2	5 3 3	2.06E-02	4	2 200	
7137.0423	-25	1 0 1	2 1 2	4.02E-02	10	3 200	7183.5930	-5	7 5 3	7 5 2	7.95E-03	3	3 101	7227.0873	0	6 3 3	6 2 4	4.10E-03	10	3 200	
7137.046	-35	5 0 5	5 2 4	4.72E-03	10	3 101	7183.5871	74	5 5 1	5 5 0	7.55E-02	2	2 101	7227.283	-62	5 0 5	4 2 2	8.00E-04	15	1.07	2 101
7138.183	0	8 7 1	8 7 2	1.17E-03	15	2 101	7183.756	6	1 0 2	2 1 1	7.92E-02	2	3 101	7227.4215	20	2 2 0	2 1 1	1.88E-02	5	3 200	
7138.438	234	4 1 4	5 3 2	1.77E-03	15	2 200	7183.8951	0	7 5 2	7 5 3	2.49E-03	15	3 101	7228.3008	-83	1 1 1	0 0 0	1.17E-02	3	3 200	
7139.0005	52	7 2 6	7 2 5	4.60E-03	10	3 101	7184.45616	-7	1 1 1	2 2 2	2.44E-01	3	2 101	7229.34772	10	2 2 1	2 2 0	1.39E-01	5	3 101	
7139.328	-219	2 2 1	3 1 2	9.05E-04	15	2 200	7186.8929	41	6 3 4	6 3 3	5.35E-03	10	0.96	7229.658	-591	2 2 0	3 0 3	1.13E-03	15	3 101	
7139.487	61	3 1 3	4 2 2	3.07E-03	10	2 200	7188.6432	0	6 5 2	6 5 1	7.64E-03	3	3 101	7230.2395	10	4 1 3	4 0 4	6.30E-03	15	2 200	
7139.6865	-2	3 0 3	4 0 4	1.10E-01	2	2 101	7188.7026	4	6 5 1	6 5 2	2.28E-02	3	3 101	7231.26139	-8	1 1 1	1 1 0	2.94E-0			

Table 5. (continued)

observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J _{K_aK_c}	lower J _{K_aK_c}	observed strength %	R ^b	mol band ^c
7251.1248	0	9 5 4	9 4 5	5.15E-04	10	3 200	7287.208	71	5 0 5	6 1 6	1.70E-03	15	2 002	7325.290	50	5 1 4	4 4 1	1.50E-03	15	2 002
7251.1773	-8	5 2 3	5 2 4	3.32E-03	10	3 101	7287.553	0	6 0 6	6 5 1	4.10E-04	10	2 200	7326.058	123	4 3 2	4 1 3	1.17E-03	10	3 101
7251.1883	9	2 1 1	2 1 2	1.42E-01	4	3 101	7287.590	-237	6 6 1	6 5 2	1.22E-03	10	2 200	7326.716	480	7 2 6	6 1 5	2.35E-03	10	0.92 2 200
7251.5809	5	3 2 0	3 2 1	2.68E-02	4	3 200	7288.016	-19	3 1 2	4 2 3	8.23E-04	15	2 002	7326.846	-30	1 1 0	2 2 1	7.04E-04	15	2 002
7251.701	-149	3 2 1	4 3 2	4.33E-04	10	3 002	7288.3586	-51	6 0 6	5 1 5	1.45E-03	3	3 101	7326.8735	0	6 2 3	5 1 4	1.63E-02	5	3 200
7251.968	52	3 2 1	2 0 2	1.72E-02	6	2 200	7289.0126	-5	6 0 6	5 1 5	1.45E-03	3	2 200	7326.4754	85	7 2 6	7 0 7	4.35E-03	6	0.92 2 101
7252.017	-614	1 0 1	0 0 0	8.05E-02	10	2 101	7289.4494	49	7 2 6	7 1 7	9.35E-04	10	2 101	7326.420	137	6 5 2	5 5 1	4.00E-03	7	2 101
7252.607	-83	8 2 6	8 1 7	5.00E-04	15	2 200	7289.6871	-58	5 1 4	5 1 5	6.92E-03	10	2 101	7326.6432	45	6 5 1	5 5 0	1.20E-02	7	2 101
7253.6585	-88	4 1 3	3 2 2	1.68E-03	10	3 200	7289.84775	1	3 2 2	2 2 1	1.21E-01	3	2 101	7326.39857	-6	5 3 3	4 3 2	1.19E-01	2	2 101
7253.881	39	5 1 4	5 0 5	1.30E-02	10	3 200	7290.5244	2	6 1 6	5 0 5	2.40E-02	3	0.96 2 200	7326.473	-601	3 3 0	3 0 3	1.91E-03	15	3 200
7254.0317	-1	5 3 3	5 2 4	1.17E-02	10	2 200	7290.9931	1	3 0 3	2 0 2	1.54E-01	3	2 101	7326.818	143	8 1 7	7 2 6	1.10E-03	15	2 200
7255.1234	-16	3 1 2	3 1 3	2.63E-02	4	1.02 2 101	7291.9085	74	7 2 5	7 2 6	8.30E-04	10	3 101	7326.8407	-22	5 4 2	4 4 1	3.98E-02	3	3 101
7255.487	478	5 1 4	6 2 5	7.46E-04	10	2 002	7292.1314	0	7 6 1	7 5 2	8.20E-04	10	3 200	7326.9217	23	9 0 9	8 1 8	6.15E-03	10	1.45 2 200
7255.7889	15	6 1 5	5 3 2	2.63E-03	5	3 101	7292.968	24	4 2 3	4 0 4	6.10E-03	10	1.00 2 101	7327.029	-15	9 1 9	8 0 8	2.03E-03	10	2 200
7255.8440	40	4 2 3	4 1 4	1.10E-02	3	3 200	*7293.686	171	7 7 0	7 6 1	4.90E-04	15	2 200	7327.3202	-8	5 4 1	4 4 0	1.34E-02	4	3 101
7256.5167	31	6 4 2	6 3 3	2.61E-03	7	3 200	*7293.873	67	8 2 7	8 1 8	7.55E-03	10	2 200	7327.3847	38	5 0 3	4 1 4	1.87E-03	5	2 002
7257.2755	-13	4 1 5	3 2 2	1.01E-02	4	1.09 2 200	7293.9236	-5	6 1 5	5 2 4	2.40E-03	10	3 200	7327.4473	83	3 3 1	2 2 0	3.81E-03	5	3 200
7257.3955	-33	3 3 1	3 2 2	1.05E-02	3	3 200	7294.3033	-8	3 2 2	2 1 0	2.08E-02	5	3 200	7327.5120	-7	5 2 4	4 2 3	2.32E-01	2	2 101
7257.5660	-24	4 0 4	3 1 3	1.24E-02	5	1.05 2 200	7294.7737	-43	2 2 1	2 0 2	3.17E-03	10	3 101	7328.5749	-2	5 1 5	4 1 4	4.02E-01	10	3 101
7258.453	-172	5 2 4	5 1 5	2.56E-03	10	2 200	7294.781	175	7 2 5	6 3 4	6.00E-04	15	2 200	7328.8713	-6	3 3 0	2 2 1	1.28E-02	5	3 200
7258.4833	0	4 3 2	4 2 3	4.08E-02	4	3 200	*7295.06368	-6	3 2 1	2 2 0	7.22E-02	3	2 101	7329.4477	15	4 2 2	3 2 1	2.57E-01	3	3 101
7258.7664	-4	7 4 4	7 3 5	1.77E-03	4	1.09 2 200	7295.2980	33	2 1 2	2 2 1	4.42E-04	15	3 002	7330.5536	4	5 0 5	4 0 4	1.20E-01	3	3 101
7258.9445	-16	8 4 5	8 3 6	2.34E-03	6	1.02 2 200	7295.6324	-9	3 1 3	2 1 2	4.55E-01	4	3 101	*7331.109	119	7 6 2	6 6 1	2.87E-03	10	2 101
7259.189	-43	7 3 5	7 2 6	6.00E-04	15	2 200	7296.5741	-80	6 0 6	6 5 1	8.35E-03	10	3 200	7331.1162	-30	5 3 2	4 3 1	3.90E-02	10	2 101
7259.5850	32	3 1 3	2 0 2	1.67E-02	4	3 200	7296.770	550	6 0 6	6 5 1	8.35E-04	15	3 200	7331.761	179	3 3 1	3 1 2	1.45E-03	10	3 101
7259.764	0	8 2 6	8 1 7	3.48E-04	15	3 200	7296.783	44	8 2 6	8 2 7	2.26E-03	10	2 101	7332.0185	-50	2 2 0	1 0 1	7.25E-03	10	0.87 2 101
7259.764	-32	6 3 4	6 2 5			3 200	7296.8006	-1	6 6 1	6 5 2	1.58E-03	15	3 101	7332.3922	-29	7 1 6	7 1 7	2.15E-03	15	3 101
7259.8830	37	6 4 3	6 3 4	8.58E-03	4	0.96 2 200	7297.2425	-20	3 2 2	3 0 3	1.83E-02	2	3 101	7332.634	-2	7 2 6	6 1 5	2.60E-03	15	3 200
7260.1353	0	6 2 5	7 1 6	5.60E-04	15	3 002	7298.1542	14	6 1 6	5 0 5	2.66E-02	4	3 200	7332.6346	22	4 1 3	3 1 2	3.21E-01	5	2 101
7260.647	85	2 2 1	3 3 0	5.40E-04	10	2 002	7299.0896	0	4 2 3	3 1 2	4.37E-02	4	2 200	7333.1769	16	8 2 7	7 1 6	3.70E-03	10	2 200
7261.8743	0	1 0 1	0 0 0	7.95E-02	5	3 101	7299.2655	31	5 0 5	6 1 6	1.93E-03	10	3 002	7333.2612	-11	6 1 6	5 1 5	9.06E-02	3	2 101
7262.158	26	5 4 2	5 3 3	5.00E-03	10	2 200	7299.393	-51	5 1 4	5 1 5	6.12E-03	3	3 101	7333.6175	0	5 1 4	4 4 1	1.63E-03	10	3 002
7262.6285	-40	5 3 3	5 2 4	1.25E-02	5	3 200	7299.635	-5	3 2 2	2 2 1	2.00E-01	10	3 101	7333.812	-9	3 1 3	4 0 4	7.03E-04	15	2 002
7263.2454	-1	6 1 5	6 0 6	1.90E-03	5	0.95 2 200	7299.7699	0	3 1 2	4 2 3	1.33E-03	15	3 002	7334.1608	5	6 0 6	5 0 5	2.78E-04	4	2 101
7263.495	-65	4 0 4	3 1 4	4.15E-03	10	1.02 2 200	*7300.9517	-6	3 0 3	2 0 2	1.62E-02	2	3 101	7334.224	0	8 1 7	7 2 6	1.10E-03	15	3 200
7264.0628	-5	6 2 4	6 2 5	2.07E-02	4	1.03 2 101	7301.1351	-50	6 1 5	5 2 4	2.43E-03	4	3 200	7334.4008	0	9 0 9	8 1 8	4.30E-03	6	3 200
7264.8243	19	3 1 2	3 1 3	2.51E-02	5	3 101	7301.333	193	7 2 5	6 3 4	5.23E-04	10	3 200	7334.7397	0	9 1 9	8 0 8	1.42E-03	6	3 200
7264.863	64	4 1 4	3 0 3	4.35E-02	10	2 200	7301.4405	-52	8 2 7	8 1 8	1.40E-03	15	3 200	7335.133	-349	6 5 2	5 5 1	3.80E-03	4	3 101
7264.873	12	4 1 4	4 3 2	1.23E-02	10	2 200	7301.9029	-7	3 1 2	2 1 1	1.15E-01	3	2 101	7335.155	-120	6 5 1	5 5 0	1.14E-02	4	3 101
7264.9801	16	4 0 4	3 1 3	1.24E-02	5	3 200	7302.0862	70	5 2 4	5 0 5	1.48E-02	3	1.05 2 101	7335.4360	-36	7 2 6	7 0 7	4.62E-03	10	3 101
7265.5281	-145	7 5 2	7 4 3	2.44E-03	4	1.00 2 200	7302.5504	48	7 0 7	6 1 6	1.47E-02	4	2 200	7336.0883	-12	5 3 3	4 3 2	1.21E-01	2	3 101
7265.9275	4	5 4 1	5 3 2	1.28E-02	5	3 200	7303.8915	6	4 1 4	3 1 3	1.47E-01	2	3 101	7336.3849	-6	6 4 3	5 4 2	8.44E-03	10	2 101
7266.0765	36	6 0 6	7 1 7	4.00E-04	10	2 002	7303.9917	26	4 2 3	4 0 4	6.39E-03	7	3 101	7336.521	-183	8 1 7	8 1 8	2.23E-03	10	0.93 2 101
7266.0878	-12	5 2 4	5 1 5	2.80E-03	5	3 200	7303.2077	-7	7 1 7	6 0 6	5.00E-03	10	2 200	7336.6729	-27	1 1 0	2 2 1	7.51E-04	10	3 002
7266.255	0	6 1 6	7 0 7	1.20E-03	15	2 002	*7303.5252	0	7 0 7	6 1 6	5.70E-04	15	3 200	7337.3312	-35	5 2 4	4 2 3	2.24E-01	3	3 101
7267.1224	685	5 1 4	6 2 5	7.46E-04	15	3 002	7304.320	-242	6 3 4	6 1 5	1.86E-03	10	2 101	7337.819	-29	8 2 7	8 0 8	7.00E-04	10	2 101
7267.2798	0	7 4 4	7 3 5	1.89E-03	10	3 200	7304.7656	25	3 2 1	2 2 0	7.50E-02	2	3 101	7337.9688	-565	10 0 10	9 1 9	1.31E-03	10	2 200
7267.326	95	8 3 6	8 2 7	7.90E-04	15	2 200	7305.9119	-6	4 3 2	3 3 1	3.60E-02	3	2 101	7338.035	3	4 3 2	3 2 1	9.05E-04	15	2 200
7267.3607	-12	2 1 2	1 1 1	1.05E-01	4	2 101	7306.084	-9	4 2 3	5 1 4	5.02E-04	15	2 002	7338.238	194	10 1 10	9 0 9	1.51E-03	10	2 200
7267.606	98	9 2 7	9 1 8	5.50E-04	15	2 200	7306.2645	18	8 2 6	8 2 7	2.77E-03	10	3 101	7339.0357	205	9 1 8	8 2 7	1.75E-03	10	2 200
7267.745	92	8 4 5	8 3 6	2.38E-03	6	3 200	7306.3537	-28	4 0 4	3 0 3	4.30E-01	3	2 101	7339.0786	-21	6 2 2	5 4 1	3.95E-02	4	2 101
7268.4022	40	6 4 3	6 3 4	8.82E-03	3	3 200	7306.9464	16	6 1 5	6 1 6	1.10E-02	10	2 101	7339.4720	0	3 0 3	4 1 4	2.01E-03	10	3 002
7268.501	-450	7 5 3	7 4 4	8.50E-04	10	2 200	7307.0377	-4	4 2 3	3 1 2	4.25E-02	3	3 200	7340.1008	59	5 1 4	4 1 3	8.85E-02	4	2 101
7269.9213	14	6 1 5	6 0 6	4.85E-03	3	0.98 2 200	7307.288	4	7 3 5	7 1 6	2.22E-03	10	2 101	7340.337	-94	6 1 5	5 4 2	5.79E-03	15	2 002
7270.1900	33	2 2 1	1 0 1	8.10E-02	2	3 200	7307.325	-5	3 3 1	3 1 4	4.60E-03	10	2 101	*7340.540	-13	6 1 5	5 4 2	5.79E-03	15	2 002
7270.543	-140	6 1 5	6 0 6	2.07E-03	10	3 200	7307.4211	-5	3 3 1	3 1 4	4.60E-0									

Table 5. (continued)

observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	observed position	o-c	upper J K _a K _c	lower J K _a K _c	observed strength %	R ^b	mol band ^c	
7357.4804	15	7 0 7	6 0 6	5.85E-02	3	3 101	7394.145	0	10 6 4	9 6 3	3.92E-04	15	3 101	7453.983	-92	7 6 1	6 5 2	1.93E-04	15	2 200	
7357.832	125	2 1 2	3 0 3	1.32E-03	10	0.72	7394.145	0	0 0 0	1 1 1	3.02E-04	15	3 102	7456.137	89	5 3 3	4 0 4	1.15E-03	10	3 200	
7358.03075	0	7 4 4	6 4 3	2.61E-02	4	1.01	7394.3412	-58	4 2 2	3 0 3	1.44E-02	5	1.07	7456.773	-397	5 3 2	2 2 3	8.06E-04	8	0.99	2 002
7358.556	-28	8 6 2	7 6 1	1.94E-03	10	3 101	7394.4650	0	11 11 10	10 10 9	1.18E-02	10	2 101	7457.287	209	4 3 2	3 1 3	8.07E-04	10	3 101	
7358.577	29	8 6 3	7 6 2	6.50E-04	10	3 101	7394.4664	-21	9 2 8	8 2 7	2.34E-02	10	3 101	7459.3982	-13	3 2 1	3 1 2	1.09E-03	10	3 002	
7358.8017	20	7 2 6	6 2 5	9.80E-02	5	2 101	7394.5352	19	11 0 10	10 10 9	1.80E-03	10	2 101	7462.674	230	3 1 2	3 0 3	2.04E-03	10	3 002	
7359.223	177	9 1 8	9 1 7	4.33E-04	15	3 101	7394.6865	7	10 2 9	9 2 8	3.30E-03	5	0.96	7462.9556	4	6 3 3	5 1 4	7.70E-03	6	1.02	2 101
7359.7019	0	10 2 9	9 2 8	1.00E-03	10	3 200	7396.1029	10	10 1 9	9 1 8	1.06E-02	10	0.99	7463.660	-274	4 3 1	4 2 2	3.42E-04	10	1.10	2 002
7359.9195	8	3 2 1	2 1 0	4.44E-03	5	2 101	7396.2627	0	9 1 8	8 1 7	1.05E-03	5	3 101	7463.9645	-9	2 2 1	2 1 2	8.20E-04	10	0.80	2 002
7359.9616	17	8 1 8	7 1 7	3.45E-02	5	2 101	7397.962	-132	7 2 5	6 2 4	1.06E-02	5	3 101	*7464.665	-11	7 7 0	6 6 1	7.14E-04	10	2 200	
7360.034	-252	9 2 8	9 0 0	1.65E-03	15	3 101	7398.2439	5	8 2 6	7 2 5	3.11E-02	4	2 101	7464.818	80	4 1 3	4 0 4	3.97E-04	10	0.85	2 002
7360.12933	0	8 0 8	7 0 7	1.08E-01	3	2 101	7399.157	-221	3 3 0	2 1 1	1.14E-03	10	2 101	7470.233	43	3 3 0	3 2 1	1.00E-03	10	1.30	2 002
7360.896	-247	6 0 6	5 0 5	3.20E-03	10	3 002	7399.3997	-101	8 3 5	7 3 4	2.30E-02	8	2 101	7470.4166	-192	2 1 2	1 0 1	1.34E-03	10	0.95	2 002
7361.064	29	7 4 3	6 4 2	8.40E-03	10	2 101	7399.8566	36	5 5 1	4 4 0	1.21E-03	10	2 200	7470.947	-63	4 4 0	3 3 1	8.85E-04	10	0.99	2 101
7361.064	23	10 1 9	10 1 8	3.90E-04	15	2 101	7399.9195	-78	5 5 0	4 4 1	4.02E-03	10	2 200	7471.178	232	3 2 2	3 1 3	3.99E-04	10	0.95	2 002
7361.8574	-1	4 4 1	3 3 0	1.13E-02	10	2 200	7399.951	-197	1 0 1	1 0 0	2.09E-03	4	0.02	7472.2247	47	3 0 3	2 1 2	2.95E-04	10	1.22	2 002
7362.1032	-39	4 4 0	3 3 1	3.85E-03	10	1.17	7402.2192	-25	9 4 6	8 4 5	7.10E-03	10	3 101	7473.3417	18	6 3 3	5 1 4	7.99E-03	10	3 101	
7362.6784	-3	5 3 3	4 2 2	1.03E-02	4	3 200	7402.5007	0	9 3 7	8 3 6	1.26E-02	5	3 101	7475.737	-652	7 2 5	7 1 6	3.22E-04	10	2 002	
7362.9875	-25	1 0 1	2 1 2	1.72E-03	10	1.05	7404.133	400	11 10 10	10 1 9	1.15E-03	10	1.04	7476.644	50	2 2 1	2 1 2	8.55E-04	15	3 002	
7363.5992	-46	7 3 5	6 3 4	5.30E-02	3	2 101	7404.3448	-91	4 2 2	3 0 3	1.41E-02	8	3 101	7476.644	-300	4 3 1	4 2 2	3.52E-04	15	3 002	
7364.0839	16	6 1 5	5 1 4	1.70E-01	2	3 101	7404.3982	0	2 0 2	2 1 1	5.40E-04	15	3 002	7477.6354	-100	4 3 2	4 2 3	9.53E-04	10	1.05	2 002
7364.419	-85	8 6 4	7 5 3	2.10E-03	10	1.03	7404.529	-51	12 0 12	11 1 11	5.90E-03	10	2 101	7480.6155	-55	4 2 3	4 1 4	1.12E-03	10	0.97	2 002
7364.542	-160	7 3 5	6 2 4	4.34E-03	10	2 200	7404.6042	-13	11 1 11	10 1 10	1.13E-02	4	3 101	7481.8615	-19	5 3 3	4 1 4	2.11E-03	10	3 101	
7364.7039	-32	5 0 4	4 3 2	2.97E-04	15	3 002	7404.8414	-19	10 3 8	9 3 7	3.26E-03	10	2 101	7481.8854	-92	5 1 4	5 0 5	7.13E-04	10	2 002	
7365.0465	-3	6 3 3	5 2 2	8.30E-02	5	3 101	7404.8789	0	10 2 9	9 2 8	3.72E-03	8	3 101	7482.9597	-24	2 1 2	1 0 1	1.17E-03	10	3 002	
7365.053	140	8 5 3	7 5 2	6.10E-03	15	2 101	7404.969	75	11 2 10	10 2 9	5.37E-03	15	2 101	7485.920	-466	5 4 1	4 2 2	5.35E-04	3	2 101	
7365.3474	24	7 1 6	6 1 5	3.44E-02	4	2 101	7405.596	146	10 5 5	9 5 4	1.00E-03	15	0.94	7486.889	139	6 4 4	6 2 5	7.02E-04	10	2 002	
7365.5793	84	6 3 4	5 2 3	5.45E-02	4	3 200	7406.3057	7	10 1 9	9 1 8	1.01E-02	5	3 101	7487.283	353	4 4 1	4 3 2	2.64E-04	10	0.80	2 002
7366.265	-265	6 6 4	5 5 3	6.45E-03	15	3 200	7407.049	-46	9 4 5	8 4 4	1.83E-03	10	0.92	7490.463	104	4 3 2	4 2 3	3.10E-03	15	3 002	
7367.224	86	9 6 3	8 6 2	3.30E-04	10	2 101	7407.480	-365	10 4 7	9 4 6	9.57E-04	10	2 101	7490.466	-95	6 2 4	5 0 5	2.86E-03	4	1.03	2 101
7367.255	123	9 6 4	8 6 3	1.28E-03	10	2 101	7407.5456	0	9 2 7	8 2 6	4.45E-03	10	2 101	7492.5968	48	5 3 3	4 1 4	2.37E-03	10	3 101	
7367.7088	27	4 4 3	3 3 2	2.54E-02	15	3 101	7408.5388	-16	8 6 7	7 5 6	3.18E-02	3	3 101	7493.222	84	4 2 3	4 1 4	8.15E-04	15	3 002	
7368.7686	73	7 2 6	6 2 5	9.90E-02	5	3 101	7408.7031	0	8 3 5	7 3 4	2.25E-02	5	3 101	7494.169	346	5 1 4	5 0 5	1.14E-03	15	3 002	
7368.787	66	8 3 6	7 2 5	3.80E-03	15	2 200	7408.7739	-26	5 5 1	4 4 0	1.38E-03	10	3 200	7496.614	47	3 4 6	3 1 5	1.03E-03	5	0.81	2 101
7369.3551	-2	6 2 4	5 2 3	7.95E-02	2	2 101	7408.8320	11	5 5 0	4 4 1	4.50E-03	8	3 200	7498.580	-349	4 1 4	4 0 3	7.20E-04	15	0.76	2 002
7370.0421	0	8 1 8	7 1 7	3.46E-02	10	3 101	7409.432	-889	9 3 6	8 3 5	7.75E-04	15	2 101	7498.7131	-7	6 4 2	5 2 3	2.38E-03	4	1.04	2 101
7370.192	14	3 2 1	2 0 2	5.03E-03	10	3 101	7410.155	142	3 0 2	2 1 1	9.35E-04	10	3 101	7500.233	-70	6 2 4	5 0 5	3.10E-03	10	3 101	
7370.196	17	2 1 2	3 0 3	1.41E-03	15	3 002	7412.1680	-20	1 0 1	1 0 0	1.24E-03	10	3 002	7500.929	-81	2 2 1	1 1 0	1.80E-03	4	1.01	2 002
7370.2190	0	8 0 8	7 0 7	1.05E-01	5	3 101	7412.4984	82	4 3 2	3 0 3	1.83E-03	10	2 200	7501.2360	73	5 4 2	4 2 3	1.53E-03	5	1.26	2 101
7370.4409	22	4 4 1	3 3 0	1.00E-02	10	3 200	7413.9669	6	13 13	12 12	2.22E-03	10	1.16	7504.234	235	6 2 5	6 1 6	1.09E-03	10	1.90	2 002
7370.4409	-36	7 4 3	6 4 2	7.64E-03	10	3 101	7414.205	-27	11 11 10	10 1 10	1.13E-02	4	3 101	7506.558	-166	7 3 6	6 1 5	9.17E-04	10	3 101	
7370.6795	-59	4 4 0	3 3 2	3.47E-03	5	3 200	7414.5629	0	11 10 10	10 1 9	1.21E-03	10	3 101	7507.722	-60	2 0 1	1 1 1	4.12E-04	15	0.77	2 002
7372.1338	-1	8 2 7	7 2 6	1.83E-02	3	1.04	7414.6484	-43	12 12	11 0 11	5.88E-03	15	3 101	7508.722	-294	5 0 5	4 1 4	6.60E-04	10	2 002	
7372.261	9	9 1 9	8 1 8	5.80E-02	10	2 101	7414.696	-60	3 1 2	2 1 1	1.52E-03	15	0.95	7510.1957	-8	6 4 2	5 2 3	2.05E-03	10	3 101	
7372.271	-43	9 0 9	8 0 8	1.92E-02	10	2 101	7414.8443	0	10 3 8	9 3 7	1.84E-03	10	3 101	7511.1854	-14	4 1 4	4 0 3	7.20E-04	10	3 002	
7372.994	-213	7 3 5	6 2 4	4.65E-03	10	3 200	7414.9067	0	10 2 8	9 2 7	5.57E-03	10	1.11	7512.012	-137	7 4 3	6 2 4	7.00E-04	15	0.71	2 101
7373.805	-239	8 5 4	7 5 3	1.67E-03	10	3 101	7415.1330	0	11 2 10	10 2 9	4.47E-03	5	3 101	7512.608	-303	5 4 2	4 2 3	3.15E-03	10	2 101	
7374.3598	-15	8 5 3	7 5 2	4.50E-03	10	3 101	7415.434	-110	11 3 9	10 3 8	2.24E-03	10	2 101	7513.6839	0	2 2 1	1 1 0	1.97E-03	10	3 002	
7374.4576	-5	7 3 5	6 2 4	2.85E-02	6	3 101	7416.1702	0	9 4 5	8 4 4	1.83E-03	10	3 101	7517.955	-9	3 2 2	2 1 1	3.53E-04	15	2 002	
7375.1280	20	7 4 3	6 4 2	1.53E-03	10	3 002	7416.8532	7	5 1 1	4 1 0	2.64E-03	10	1.16	7520.285	-185	6 3 4	5 1 4	1.14E-03	7	2 101	
7375.557	-2	7 1 6	6 1 5	4.00E-02	15	3 101	7417.1100	0	10 7 9	9 6 8	1.18E-03	15	3 101	7526.785	-599	6 4 5	5 3 4	6.44E-04	15	0.82	2 101
7375.8270	-24	8 1 7	7 1 6	3.50E-02	4	2 101	7417.9644	0	9 2 7	8 2 6	4.86E-03	10	3 101	7529.2275	71	8 4 4	7 2 5	1.55E-03	7	0.98	2 101
7375.837	-9	3 1 2	3 0 1	3.52E-04	15	2 002	7419.9098	0	9 3 6	8 3 5	8.40E-04	10	3 101	7531.119	128	6 3 4	5 1 5	4.93E-04	15	3 101	
7376.0544	-7	8 4 5	7 4 4	4.20E-03	10	2 101	7419.915	86	6 5 2	5 4 1	1.10E-03	15	2 200	7531.5617	0	4 2 3	3 1 2	1.04E-03	5	1.04	2 002
7376.553	0	9 6 3	8 6 2	3.92E-04	15	3 101	7421.102	102	8 4 5	7 3 4	2.97E-03	15	2.75	753							

observed strength, estimated uncertainty in the measured strength in percent (%s), the ratio R of the observed strength to that given by Chevillard *et al.*³ for H_2^{18}O , the upper vibrational-state notation, and the isotopic species (mol = 2 for H_2^{18}O and mol = 3 for H_2^{17}O). The line-strength values shown were normalized for 100% of the particular molecule. Chevillard *et al.*³ reported line-strength values for a temperature of 300 K, and those were converted to values at 296 K to compute values of the ratios R for the present study. The expression used for the conversion is

$$S(296) = S(300) \times (300/296)^{5/2} \times \exp[-1.4388 E''(1/296 - 1/300)], \quad (1)$$

where S is the line strength in inverse centimeters squared per atmosphere, and E'' is the lower-state vibration-rotation energy in inverse centimeters.

In Table 5, the observed line positions are given to 3, 4, or 5 places past the decimal, and each is an indication of the accuracy of the measurement. The most accurately determined values are given to five places, and these values are known to $\pm 0.00006 \text{ cm}^{-1}$ in precision, whereas the absolute uncertainty is estimated to be $\pm 0.0001 \text{ cm}^{-1}$. The computed frequencies were derived from the term values given in Tables 3 and 4 and the ground-state values given in Ref. 6.

The estimated uncertainties %s in the measured strengths given in Table 5 vary from 2% to 15%. Measurements with %s $\leq 10\%$ reflect the true uncertainty of the measurements, and those with %s = 15% have a large range of uncertainty attached to the line strength value: from possibly less than 10% to as much as 100%. This rather large span was found to be due to one or more of the following reasons: (a) blending, (b) weakness of the absorption in all of the spectra, and (c) poor agreement between the strength values derived from the various spectra for a given transition. Absorptions marked with an asterisk denote double lines of comparable transitions of the same isotope and band, and the strength listed represent the sum of the strengths of the two lines. The rotational quantum assignments shown represent the stronger transition from which the computed frequency was determined.

Discussion

The transition frequencies and strengths measured in this study and the measurements of H_2^{18}O reported by Chevillard *et al.*³ provide a need addition to the HITRAN⁷ data base, which does not at this time contain information on H_2^{17}O and H_2^{18}O in the 1.4- μm spectral region. However, to derive reliable, computed line-strength values in this region, a six-band interactive quantum mechanical model is required. The model would initially be tested and utilized with the H_2^{16}O data included in a recent report.¹

The author thanks the Kitt Peak National Observatory for the use of the Fourier transform spectrometer and J. Wagner and C. Plymate for their assistance in obtaining the H_2O spectra. The Atmospheric Trace Molecule Spectroscopy (ATMOS) dedicated computer facility was used in the analysis of the experimental data. The research described in this paper was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

References

1. R. A. Toth, "Extensive measurements of H_2^{16}O line frequencies and strengths: 5750 to 7965 cm^{-1} ," *Appl. Opt.* **33**, 4851-4867 (1994).
2. R. A. Toth, J.-M. Flaud, and C. Camy-Peyret, "Spectrum of H_2^{18}O and H_2^{17}O in the 6974 to 7387 cm^{-1} region," *J. Mol. Spectrosc.* **67**, 206-218 (1977).
3. J.-P. Chevillard, J.-Y. Mandin, C. Camy-Peyret and J.-M. Flaud, "The first hexad $\{040\}$, $\{120\}$, $\{021\}$, $\{200\}$, $\{101\}$, $\{002\}$ of H_2^{18}O : experimental energy levels and line intensities," *Can. J. Phys.* **64**, 746-761 (1986).
4. R. A. Toth, "The $2\nu_2 - \nu_2$ and $2\nu_2$ bands of H_2^{16}O , H_2^{17}O , and H_2^{18}O : line positions and strengths," *J. Opt. Soc. Am. B* **10**, 1526-1544 (1993).
5. R. A. Toth, " ν_2 band of H_2^{16}O : line strengths and transition frequencies," *J. Opt. Soc. Am. B* **8**, 2236-2255 (1991).
6. R. A. Toth "Transition frequencies and absolute strengths of H_2^{17}O and H_2^{18}O in the 6.2- μm region," *J. Opt. Soc. Am. B* **9**, 462-482 (1992).
7. L. S. Rothman, R. R. Gamache, R. H. Tipping, C. P. Rinsland, M. A. H. Smith, D. C. Benner, V. M. Devi, J.-M. Flaud, C. Camy-Peyret, A. Perrin, A. Goldman, S. T. Massie, L. R. Brown, and R. A. Toth, "The HITRAN molecular database: editions of 1991 and 1992," *J. Quant. Spectrosc. & Radiat. Transfer* **48**, 469-507 (1993).