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# High Frequency Transitions in the Rotational Spectrum of $SO_2$

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A large number of rotational transitions of $^{32}S^{16}O_2$, $^{34}S^{16}O_2$, and $^{32}S^{18}O^{16}O$ have been measured in the mm-, submm-, and terahertz (~1 THz) spectral regions. These data sets have been combined with all previously measured $SO_2$ microwave and selected far infrared data to obtain a highly precise set of ground state rotational constants for these isotopomers. The rotational constants for the three isotopomers are in MHz as follows:

| Parameter | $^{32}S^{16}O_2$ | $^{34}S^{16}O_2$ | $^{32}S^{18}O^{16}O$ |
|---|---|---|---|
| A | 60778.54977 (44) | 58991.18295 (51) | 59101.1690 (27) |
| B | 10318.07348 (7) | 10318.50993 (9) | 9724.64284 (56) |
| C | 8799.703399 (70) | 8761.302481 (97) | 8331.56018 (51) |

Centrifugal distortion constants up to $P^{10}$ are included in the fit. A frequency listing of all the data used in the frequency range between about 7 GHz and 1 THz is included. 

## I. INTRODUCTION

The sulfur dioxide molecule is a simple near-prolate asymmetric rotor. The rotational spectrum consists of *b*-type transitions and, as a result, covers a large range of rotational quantum numbers. Therefore, the spectrum of its various isotopic species, both in the ground and vibrational states, has long been used to test Hamiltonian models involving centrifugal distortion (*1*). For some years its spectrum has been used to calibrate spectrometers in both the microwave and infrared region. From a practical standpoint, it is one of the more significant pollutant molecules in the Earth's atmosphere, since it is produced in combustion processes and is the most important contributor to acid rain. It also plays an important role in the chemistry of Venus' atmosphere (*2*), and since its original detection in the interstellar medium by Snyder *et al.* (*3*), it has proved to be an ubiquitous and abundant constituent of star-forming regions.

In this paper, we report the measurement of a large number of high frequency (200–1050 GHz) transitions of the $^{32}S^{16}O_2$, $^{34}S^{16}O_2$, and $^{32}S^{18}O^{16}O$ isotopomers in the vibrational ground state. This new data when combined with all known previously measured transitions, especially the recent very high precision measurements of Alekseev *et al.* (*4*) and Mehrotra *et al.* (*5*), resulted in a complete set of highly precise rotational constants for these isotopomers. Since the spectrum of this molecule has proven to be of use in so many studies, we include here a complete listing of all the data used in this study.

## II. EXPERIMENTAL

The newly supplied experimental data sets consist of two parts collected in two different frequency regions by two laboratories. With the Cologne terahertz spectrometer the frequency region between 500 and 1000 GHz was scanned, whereas the RAD spectrometer of the Institute of Applied Physics provided new data in the lower frequency region, i.e., 180–380 GHz. The other data are taken from the literature.

The new $SO_2$ data taken with the Cologne terahertz spectrometer were recorded in response to high-frequency interstellar spectral line surveys in high-mass star-forming regions. In the Caltech line survey of the Orion A region in the 325–360 GHz frequency band it was found that the total integrated line intensity for all $SO_2$ lines dominates the emission (*6*). Figure 1 displays a comparison between a laboratory and astronomical recording of the $^rQ_6$ branch head at 663 GHz presented on the same frequency scale (*7*). The astronomical measurements are taken from the Caltech 607–725 GHz spectral line survey (*8*). Figure 2 shows the band-head region of the laboratory spectrum in higher frequency resolution to substantiate the *J* assignment. The Cologne terahertz spectrometer has been described in various publications, e.g., (*14, 15*). Most recently a detailed evaluation of the sensitivity and measurement accuracy of the spectrometer has been presented (*16*). Near 1 THz, lines with an absorption coefficient of $\sim 10^{-8}$ cm$^{-1}$ are clearly detectable ($\geq 5\sigma$). With the spectrometer operated in the Doppler-limited mode, the achieved frequency accuracy for isolated, strong lines is estimated to be around $\pm 5$ kHz. In



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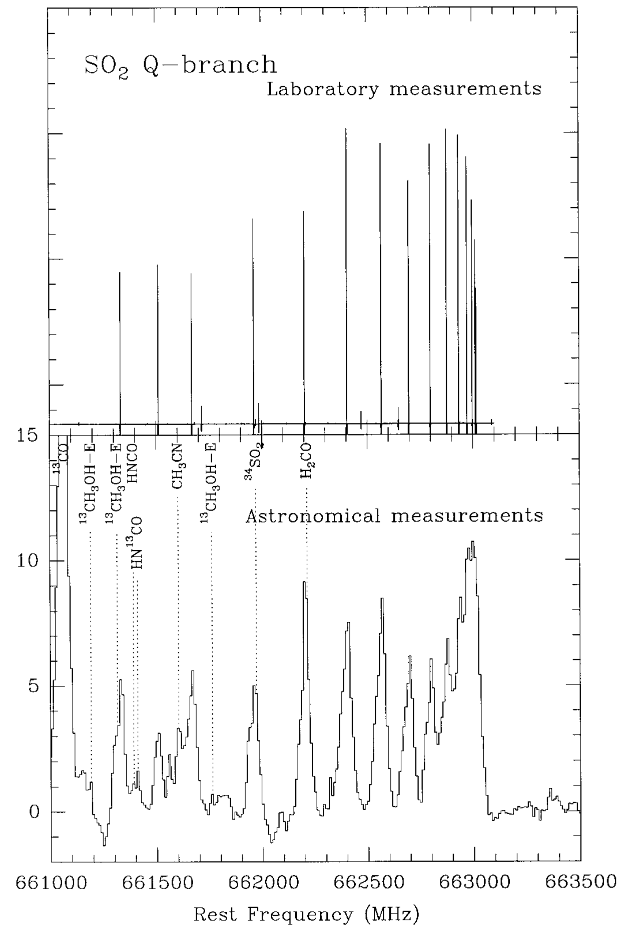


**FIG. 1.** A comparison between laboratory and interstellar spectrum of the $K_a = 6\ ^rQ_6$ band head of $SO_2$.

case the spectrometer is operated in the sub-Doppler mode, line positions are routinely determined to better than 1 kHz. The sample pressure for the $SO_2$ measurements was kept below about 3 Pa (30 $\mu$bar), and all spectra were recorded in the Doppler resolution mode. In addition to the spectra of the three isotopomers of $SO_2$ discussed in this study, we have measured the $^{33}SO_2$ isotopomeric species, and, in consequence, we have detected several emission lines of the $^{33}$S-isotopomer in the Orion A interstellar molecular cloud (*17*).

In the range 180–380 GHz the spectral lines were measured using a RAD spectrometer with a submillimeter frequency synthesizer (*13*). The measurements were made at room temperature. The gas pressure in the cell ranged from 30 to 60 Pa, corresponding to linewidths from 4 to 8 MHz. The measurements were carried out by frequency modulating the microwave radiation. The spectral lines were observed as the first derivative of the line profile. The frequency of the radiation was automatically tuned to the zero point of the response–determinator and this frequency position was measured which corresponds to the absorption maximum in the line. Predominantly isolated lines have been measured; however, in some cases small systematic errors up to 100 kHz may be caused by the influence of wings of neighboring lines, an effect that has not been taken into account in the measurements. Experimental estimates are based on systematic errors that occurred due to possible interference of the submillimeter radiation in the cell and in the microwave waveguide system elements, contributing to base-line problems. In the worst cases they cause an error up

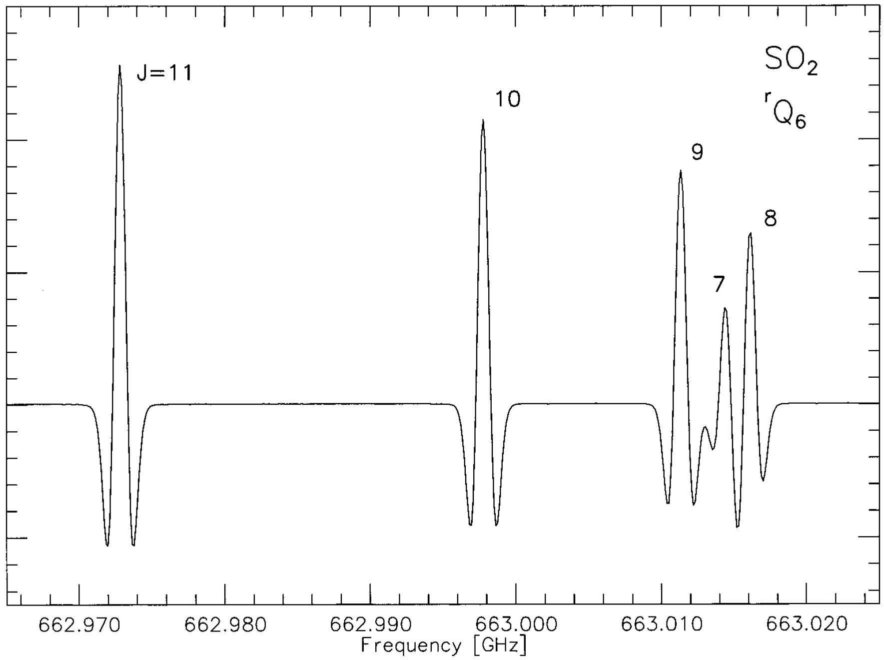


**FIG. 2.** Laboratory recording and $J$ assignment of the $^rQ_6$ band head. The line shape is of second derivative.

**TABLE 1**
**Observed Pure Rotational Transitions of $^{32}SO_2$**

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 69575.9271 | -1 | 2 | a | 12 | 3 | 9 | 12 | 2 | 10 | 237068.8700 | 33 | 150 | |
| 2 | 1 | 1 | 2 | 0 | 2 | 53528.8651 | 2 | 2 | a | 12 | 3 | 9 | 13 | 2 | 12 | 20335.4053 | 0 | 1 | b |
| 3 | 1 | 3 | 2 | 0 | 2 | 104029.4183 | 0 | 2 | a | 14 | 1 | 13 | 13 | 2 | 12 | 182705.8900 | -158 | 100 | |
| 4 | 1 | 3 | 4 | 0 | 4 | 59224.8714 | 1 | 2 | a | 15 | 3 | 13 | 15 | 2 | 14 | 275240.1500 | -38 | 300 | d |
| 5 | 1 | 5 | 4 | 0 | 4 | 135696.0200 | 3 | 80 | | 16 | 3 | 13 | 16 | 2 | 14 | 214689.3800 | -19 | 150 | |
| 6 | 1 | 5 | 6 | 0 | 6 | 68972.1587 | 0 | 2 | a | 17 | 3 | 15 | 17 | 2 | 16 | 285743.5500 | -43 | 200 | |
| 9 | 1 | 9 | 8 | 0 | 8 | 193609.4900 | 63 | 100 | | 18 | 1 | 17 | 17 | 2 | 16 | 288519.9600 | -40 | 200 | |
| 8 | 1 | 7 | 8 | 0 | 8 | 83688.0930 | 1 | 2 | a | 20 | 3 | 17 | 20 | 2 | 18 | 197142.1800 | 113 | 100 | |
| 11 | 1 | 11 | 10 | 0 | 10 | 221965.2100 | -12 | 150 | | 21 | 3 | 19 | 21 | 2 | 20 | 316099.0100 | 127 | 200 | |
| 10 | 1 | 9 | 10 | 0 | 10 | 104239.2952 | -2 | 2 | a | 22 | 3 | 19 | 22 | 2 | 20 | 195320.7000 | 276 | 100 | |
| 12 | 1 | 11 | 12 | 0 | 12 | 131014.8600 | 19 | 80 | | 24 | 3 | 21 | 24 | 2 | 22 | 200287.5300 | 102 | 150 | |
| 15 | 1 | 15 | 14 | 0 | 14 | 281762.6000 | -4 | 200 | | 26 | 3 | 23 | 26 | 2 | 24 | 213068.4000 | -33 | 150 | |
| 16 | 1 | 15 | 16 | 0 | 16 | 200809.1800 | -142 | 150 | | 29 | 3 | 27 | 28 | 2 | 26 | 616472.4100 | 128 | 100 | c |
| 15 | 3 | 13 | 16 | 0 | 16 | 239832.7540 | -68 | 60 | d | 28 | 3 | 25 | 29 | 2 | 28 | 31089.9200 | -7 | 100 | |
| 17 | 3 | 15 | 18 | 0 | 18 | 238166.3180 | -70 | 90 | d | 30 | 3 | 27 | 31 | 2 | 30 | 72437.2871 | 0 | 2 | a |
| 20 | 1 | 19 | 20 | 0 | 20 | 282292.8000 | -10 | 200 | | 32 | 3 | 29 | 33 | 2 | 32 | 119483.0800 | 3 | 80 | |
| 21 | 3 | 19 | 22 | 0 | 22 | 253753.3150 | -138 | 150 | d | 33 | 5 | 29 | 34 | 2 | 32 | 285768.2700 | 77 | 200 | |
| 27 | 3 | 25 | 28 | 0 | 28 | 314922.4280 | -289 | 300 | d | 37 | 3 | 35 | 36 | 2 | 34 | 709510.6770 | -47 | 100 | c |
| 35 | 1 | 35 | 34 | 0 | 34 | 624344.4890 | -101 | 100 | c | 38 | 3 | 35 | 39 | 2 | 38 | 275375.8900 | 204 | 450 | d |
| 38 | 1 | 37 | 38 | 0 | 38 | 624108.1380 | 19 | 100 | c | 41 | 3 | 39 | 40 | 2 | 38 | 771258.2960 | 139 | 100 | c |
| 47 | 1 | 47 | 46 | 0 | 46 | 834688.6280 | -77 | 100 | c | 41 | 5 | 37 | 42 | 2 | 40 | 288117.0860 | 27 | 120 | d |
| 46 | 1 | 45 | 46 | 0 | 46 | 766701.5200 | 116 | 100 | c | 44 | 3 | 41 | 44 | 2 | 42 | 574210.3780 | 12 | 50 | e |
| 2 | 2 | 0 | 1 | 1 | 1 | 192651.0200 | 78 | 300 | | 45 | 3 | 43 | 45 | 2 | 44 | 684929.0690 | 252 | 100 | c |
| 3 | 2 | 2 | 2 | 1 | 1 | 208700.3200 | -15 | 150 | | 46 | 3 | 43 | 46 | 2 | 44 | 616525.7320 | -54 | 100 | c |
| 2 | 2 | 0 | 2 | 1 | 1 | 151378.6300 | -32 | 80 | | 47 | 5 | 43 | 48 | 2 | 46 | 354083.9660 | -211 | 120 | d |
| 2 | 2 | 0 | 3 | 1 | 3 | 100878.1053 | -1 | 2 | a | 4 | 4 | 0 | 4 | 3 | 1 | 358038.0800 | 195 | 200 | |
| 4 | 0 | 4 | 3 | 1 | 3 | 29321.3300 | 0 | 4 | | 5 | 4 | 2 | 5 | 3 | 3 | 358013.0900 | -61 | 200 | |
| 3 | 2 | 2 | 3 | 1 | 3 | 158199.7400 | -40 | 80 | | 6 | 4 | 2 | 6 | 3 | 3 | 357925.9600 | 113 | 200 | |
| 3 | 2 | 2 | 4 | 1 | 3 | 69653.5788 | 0 | 2 | a | 7 | 4 | 4 | 8 | 3 | 5 | 204384.3000 | 110 | 100 | |
| 4 | 2 | 2 | 4 | 1 | 3 | 146605.5200 | 1 | 80 | | 8 | 4 | 4 | 9 | 3 | 7 | 185278.6000 | 262 | 100 | |
| 6 | 0 | 6 | 5 | 1 | 5 | 72758.2434 | 1 | 2 | a | 9 | 4 | 6 | 9 | 3 | 7 | 357671.7800 | -41 | 200 | |
| 4 | 2 | 2 | 5 | 1 | 5 | 70134.3728 | 0 | 2 | a | 10 | 4 | 6 | 11 | 3 | 9 | 146550.0800 | 36 | 80 | |
| 6 | 2 | 4 | 5 | 1 | 5 | 282036.5800 | 13 | 200 | | 11 | 4 | 8 | 11 | 3 | 9 | 357387.5700 | -11 | 200 | |
| 6 | 2 | 4 | 6 | 1 | 5 | 140306.1700 | 4 | 80 | | 11 | 4 | 8 | 12 | 3 | 9 | 124864.7400 | -16 | 80 | |
| 5 | 2 | 4 | 6 | 1 | 5 | 23414.2493 | 0 | 1 | b | 13 | 4 | 10 | 13 | 3 | 11 | 357165.3600 | -34 | 200 | |
| 6 | 2 | 4 | 7 | 1 | 7 | 44052.8600 | -12 | 20 | | 12 | 4 | 8 | 13 | 3 | 11 | 107843.4701 | 0 | 2 | a |
| 8 | 0 | 8 | 7 | 1 | 7 | 116980.4400 | -9 | 80 | | 14 | 2 | 12 | 13 | 3 | 11 | 47913.4200 | -6 | 20 | |
| 8 | 2 | 6 | 8 | 1 | 7 | 134004.8600 | 47 | 80 | | 15 | 2 | 14 | 14 | 3 | 11 | 7169.6130 | 0 | 1 | b |
| 8 | 2 | 6 | 9 | 1 | 9 | 24083.4781 | 0 | 1 | b | 13 | 4 | 10 | 14 | 3 | 11 | 82951.9380 | 1 | 2 | a |
| 10 | 0 | 10 | 9 | 1 | 9 | 160827.8800 | 39 | 80 | | 14 | 4 | 10 | 15 | 3 | 13 | 69464.0777 | 1 | 2 | a |
| 10 | 2 | 8 | 10 | 1 | 9 | 129514.8100 | 10 | 80 | | 15 | 4 | 12 | 15 | 3 | 13 | 357241.1900 | -8 | 200 | |
| 11 | 2 | 10 | 11 | 1 | 11 | 205300.5700 | 30 | 100 | | 16 | 2 | 14 | 15 | 3 | 13 | 104033.5817 | 0 | 2 | a |
| 12 | 0 | 12 | 11 | 1 | 11 | 203391.5500 | 66 | 100 | | 17 | 2 | 16 | 16 | 3 | 13 | 28858.0370 | 17 | 20 | |
| 10 | 2 | 8 | 11 | 1 | 11 | 11788.8410 | -34 | 20 | | 15 | 4 | 12 | 16 | 3 | 13 | 38518.2250 | 7 | 20 | |
| 12 | 2 | 10 | 12 | 1 | 11 | 128605.1300 | 18 | 80 | | 17 | 4 | 14 | 17 | 3 | 15 | 357962.8900 | -22 | 200 | |
| 12 | 2 | 10 | 13 | 1 | 13 | 8420.2800 | 5 | 40 | | 16 | 4 | 12 | 17 | 3 | 15 | 31922.2100 | -61 | 30 | |
| 14 | 2 | 12 | 14 | 1 | 13 | 132744.8600 | 26 | 80 | | 19 | 2 | 18 | 18 | 3 | 15 | 43016.2800 | 3 | 100 | |
| 14 | 2 | 12 | 15 | 1 | 15 | 14587.6970 | -64 | 20 | | 21 | 2 | 20 | 20 | 3 | 17 | 48120.4400 | 8 | 30 | |
| 16 | 0 | 16 | 15 | 1 | 15 | 283464.6000 | -172 | 200 | b | 22 | 2 | 20 | 21 | 3 | 19 | 286416.3200 | 45 | 200 | |
| 16 | 2 | 14 | 16 | 1 | 15 | 143057.1100 | 28 | 80 | | 23 | 2 | 22 | 22 | 3 | 19 | 43178.1400 | -28 | 100 | |
| 17 | 4 | 14 | 16 | 1 | 15 | 1030310.9730 | -34 | 50 | e | 24 | 4 | 20 | 24 | 3 | 21 | 296535.4900 | 57 | 200 | |
| 17 | 2 | 16 | 17 | 1 | 17 | 273752.8220 | -144 | 90 | d | 25 | 2 | 24 | 24 | 3 | 21 | 27932.2000 | -211 | 200 | |
| 16 | 2 | 14 | 17 | 1 | 17 | 30205.5200 | -26 | 100 | | 26 | 4 | 22 | 26 | 3 | 23 | 280807.2800 | 24 | 200 | |
| 18 | 2 | 16 | 18 | 1 | 17 | 160342.9900 | 16 | 80 | | 32 | 2 | 30 | 31 | 3 | 29 | 571532.5510 | -1 | 50 | e |
| 18 | 2 | 16 | 19 | 1 | 19 | 54633.5933 | 2 | 2 | a | 36 | 4 | 32 | 36 | 3 | 33 | 281688.9800 | 47 | 200 | |
| 20 | 0 | 20 | 19 | 1 | 19 | 358215.6400 | 0 | 200 | | 40 | 4 | 36 | 41 | 3 | 39 | 54138.8000 | -272 | 300 | |
| 20 | 2 | 18 | 20 | 1 | 19 | 184969.8000 | -26 | 100 | | 41 | 6 | 36 | 42 | 3 | 39 | 308232.6850 | 57 | 120 | d |
| 20 | 2 | 18 | 21 | 1 | 21 | 86828.9381 | -1 | 2 | a | 42 | 4 | 38 | 43 | 3 | 41 | 108915.4234 | 0 | 2 | a |
| 22 | 2 | 20 | 23 | 1 | 23 | 125427.1300 | -120 | 80 | | 48 | 4 | 44 | 48 | 3 | 45 | 530380.6950 | -21 | 100 | c |
| 26 | 2 | 24 | 26 | 1 | 25 | 296168.7100 | 28 | 200 | | 50 | 4 | 46 | 50 | 3 | 47 | 580132.5010 | 130 | 100 | c |
| 26 | 2 | 24 | 27 | 1 | 27 | 215094.5400 | 25 | 150 | | 55 | 6 | 50 | 56 | 3 | 53 | 334273.7220 | -360 | 150 | d |
| 31 | 2 | 30 | 30 | 1 | 29 | 576042.0560 | -22 | 100 | c | 8 | 5 | 3 | 9 | 4 | 6 | 287485.4400 | -65 | 200 | |
| 32 | 0 | 32 | 31 | 1 | 31 | 571553.3180 | -7 | 150 | e | 13 | 5 | 9 | 12 | 4 | 8 | 708392.5420 | 77 | 100 | c |
| 31 | 4 | 28 | 32 | 1 | 31 | 276254.6230 | 40 | 180 | d | 12 | 5 | 7 | 13 | 4 | 10 | 209936.0500 | 8 | 140 | |
| 35 | 2 | 34 | 35 | 1 | 35 | 571383.1230 | 44 | 100 | c | 13 | 5 | 9 | 14 | 4 | 10 | 190148.6500 | 51 | 100 | |
| 37 | 2 | 36 | 37 | 1 | 37 | 606896.4460 | -67 | 100 | c | 15 | 5 | 11 | 16 | 4 | 12 | 150381.1000 | 28 | 80 | |
| 40 | 0 | 40 | 39 | 1 | 39 | 712010.5540 | 78 | 100 | c | 18 | 3 | 15 | 17 | 4 | 14 | 9403.2420 | 7 | 12 | b |
| 40 | 2 | 38 | 40 | 1 | 39 | 590076.6690 | 37 | 100 | c | 16 | 5 | 11 | 17 | 4 | 14 | 131274.9300 | 68 | 80 | |
| 54 | 0 | 54 | 53 | 1 | 53 | 957178.8660 | 67 | 450 | e | 17 | 5 | 13 | 18 | 4 | 14 | 109757.5851 | 0 | 2 | a |
| 4 | 3 | 1 | 5 | 2 | 4 | 160543.0600 | 36 | 80 | | 20 | 3 | 17 | 19 | 4 | 16 | 61636.1885 | 0 | 2 | a |
| 5 | 3 | 3 | 6 | 2 | 4 | 139355.0600 | 30 | 80 | | 18 | 5 | 13 | 19 | 4 | 16 | 91550.4392 | -1 | 2 | a |
| 8 | 1 | 7 | 7 | 2 | 6 | 25392.8195 | 0 | 1 | b | 19 | 5 | 15 | 20 | 4 | 16 | 67848.6332 | 1 | 2 | a |
| 6 | 3 | 3 | 7 | 2 | 6 | 123057.6900 | 3 | 80 | | 21 | 3 | 19 | 20 | 4 | 16 | 37351.8000 | -10 | 100 | |
| 7 | 3 | 5 | 8 | 2 | 6 | 97702.3335 | 0 | 2 | a | 22 | 3 | 19 | 21 | 4 | 18 | 118577.4300 | 2 | 2 | a |
| 10 | 1 | 9 | 9 | 2 | 8 | 76412.1651 | 0 | 2 | a | 20 | 5 | 15 | 21 | 4 | 18 | 51736.5900 | -67 | 30 | |
| 8 | 3 | 5 | 9 | 2 | 8 | 86639.0877 | -1 | 2 | a | 23 | 3 | 21 | 22 | 4 | 18 | 66724.8768 | 0 | 2 | a |
| 9 | 3 | 7 | 10 | 2 | 8 | 53015.2374 | 0 | 2 | a | 21 | 5 | 17 | 22 | 4 | 18 | 24039.6410 | 11 | 20 | |
| 12 | 1 | 11 | 11 | 2 | 10 | 129105.8300 | 44 | 80 | | 22 | 5 | 17 | 23 | 4 | 20 | 12132.4000 | -63 | 200 | |
| 10 | 3 | 7 | 11 | 2 | 10 | 52051.7100 | -50 | 30 | | 25 | 3 | 23 | 24 | 4 | 20 | 90548.1474 | 0 | 2 | a |
| 11 | 3 | 9 | 12 | 2 | 10 | 4546.0180 | 6 | 20 | | 27 | 3 | 25 | 26 | 4 | 22 | 107060.2085 | -3 | 2 | a |

[a] Alekseev *et al.*
[b] Merotra *et al.*
[c] Helminger and deLucia.
[d] Measurements taken at Nizhni Novgorod.
[e] Measurements taken at Cologne.
All other frequencies are from the compilation of Lovas.

**TABLE 1**—*Continued*

| Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| 29 3 27 28 4 24 | 114565.3704 | 0 | 2 | a | 31 8 24 32 7 25 | 143357.8000 | -22 | 80 | |
| 31 3 29 30 4 26 | 111755.0214 | 0 | 2 | a | 32 8 24 33 7 27 | 123194.7000 | 4 | 80 | |
| 33 3 31 32 4 28 | 97994.0891 | 0 | 2 | a | 33 8 26 34 7 27 | 102690.0611 | -2 | 2 | a |
| 35 3 33 34 4 30 | 73430.4271 | 2 | 2 | a | 35 6 30 34 7 27 | 25049.4513 | 0 | 1 | b |
| 37 3 35 36 4 32 | 38909.7000 | 0 | 100 | | 36 6 30 35 7 29 | 51185.2200 | -23 | 60 | |
| 41 5 37 41 4 38 | 517100.0990 | 15 | 100 | c | 35 8 28 36 7 29 | 61489.8551 | 1 | 2 | a |
| 49 5 45 49 4 46 | 619796.1810 | 52 | 100 | c | 37 6 32 36 7 29 | 67011.2900 | 22 | 40 | |
| 50 5 45 51 4 48 | 32829.9300 | 29 | 100 | | 36 8 28 37 7 31 | 41177.5000 | 43 | 100 | |
| 52 5 47 52 4 48 | 464664.6440 | 39 | 100 | c | 38 6 32 37 7 31 | 97466.3665 | -1 | 2 | a |
| 54 5 49 54 4 50 | 515421.6590 | -19 | 100 | c | 37 8 30 38 7 31 | 19637.0642 | 0 | 1 | b |
| 56 5 51 56 4 52 | 568464.5950 | -43 | 100 | c | 39 6 34 38 7 31 | 108955.9153 | 1 | 2 | a |
| 58 5 53 58 4 54 | 621617.9680 | 79 | 100 | c | 40 6 34 39 7 33 | 146393.7200 | 14 | 80 | |
| 6 6 0 5 5 1 | 676484.3980 | -26 | 100 | c | 41 6 36 40 7 33 | 150486.9200 | -11 | 80 | |
| 8 6 2 7 5 3 | 714779.5830 | 36 | 100 | c | 42 6 36 41 7 35 | 198847.8600 | 26 | 100 | |
| 11 6 6 10 5 5 | 772188.2500 | 143 | 100 | c | 43 6 38 42 7 35 | 191020.8900 | -41 | 100 | |
| 11 6 6 12 5 7 | 331580.2440 | 45 | 90 | d | 49 6 44 48 7 41 | 297256.7670 | -245 | 90 | d |
| 14 6 8 13 5 9 | 829477.9530 | 25 | 100 | c | 48 8 40 48 7 41 | 718681.0460 | 68 | 100 | c |
| 13 6 8 14 5 9 | 292882.6970 | 115 | 60 | d | 50 6 44 49 7 43 | 461410.2010 | -11 | 100 | c |
| 17 6 12 18 5 13 | 214728.3300 | 48 | 150 | | 55 6 50 54 7 47 | 350110.3710 | 35 | 450 | d |
| 18 6 12 19 5 15 | 195080.4400 | 152 | 100 | | 9 9 1 9 8 2 | 864511.7740 | -4 | 50 | e |
| 20 6 14 19 5 15 | 943211.5370 | -126 | 100 | c | 10 9 1 10 8 2 | 864531.6090 | -7 | 50 | e |
| 20 6 14 21 5 17 | 155389.6200 | -7 | 80 | | 11 9 3 11 8 4 | 864549.0520 | -12 | 50 | e |
| 21 6 16 22 5 17 | 134943.3000 | 8 | 80 | | 10 9 1 11 8 4 | 653928.0550 | 29 | 30 | e |
| 24 4 20 23 5 19 | 22482.5595 | 0 | 1 | b | 12 9 3 12 8 4 | 864562.8660 | -8 | 60 | e |
| 23 6 18 23 5 19 | 556959.9090 | 1 | 140 | c | 13 9 5 13 8 6 | 864571.6120 | -76 | 70 | e |
| 22 6 16 23 5 19 | 115317.5566 | 0 | 2 | a | 15 9 7 15 8 8 | 864568.3010 | -16 | 60 | e |
| 23 6 18 24 5 19 | 94064.6950 | 0 | 2 | a | 16 9 7 16 8 8 | 864552.8320 | -14 | 60 | e |
| 25 4 22 24 5 19 | 26776.5740 | -15 | 20 | | 17 9 9 17 8 10 | 864525.7850 | -21 | 50 | e |
| 24 6 18 25 5 21 | 74866.5109 | 1 | 2 | a | 20 9 11 21 8 14 | 461875.9050 | 11 | 100 | c |
| 26 4 22 25 5 21 | 72668.0566 | -1 | 2 | a | 29 9 21 30 8 22 | 286651.4600 | 80 | 200 | |
| 27 4 24 26 5 21 | 64277.1759 | 0 | 2 | a | 33 9 25 34 8 26 | 207421.3800 | -83 | 150 | |
| 25 6 20 26 5 21 | 52188.4800 | -4 | 60 | | 34 9 25 35 8 28 | 187446.7500 | 17 | 100 | |
| 26 6 20 27 5 23 | 34097.7200 | -26 | 30 | | 36 9 27 37 8 30 | 147239.2800 | -14 | 80 | |
| 28 4 24 27 5 23 | 127428.2300 | 30 | 80 | | 37 9 29 38 8 30 | 126962.4600 | -53 | 80 | |
| 27 6 22 28 5 23 | 8911.1660 | 53 | 103 | b | 40 7 33 39 8 32 | 23034.8144 | 0 | 1 | b |
| 29 4 26 28 5 23 | 99392.5129 | 0 | 2 | a | 38 9 29 39 8 32 | 106674.8279 | -1 | 2 | a |
| 30 4 26 29 5 25 | 187370.3300 | 121 | 100 | | 41 7 35 40 8 32 | 42680.0900 | 23 | 100 | |
| 31 4 28 30 5 25 | 130859.4000 | -26 | 80 | | 39 9 31 40 8 32 | 86153.7638 | 0 | 2 | a |
| 32 4 28 31 5 27 | 252563.7490 | -143 | 150 | d | 42 7 35 41 8 34 | 66761.1093 | 0 | 2 | a |
| 43 4 40 42 5 37 | 153677.1400 | -16 | 80 | | 40 9 31 41 8 34 | 65714.0922 | -1 | 2 | a |
| 45 4 42 44 5 39 | 120023.4000 | -82 | 80 | | 43 7 37 42 8 34 | 85246.9990 | 1 | 2 | a |
| 45 6 40 45 5 41 | 565066.2300 | -53 | 100 | c | 41 9 33 42 8 34 | 44875.8600 | -37 | 30 | |
| 46 4 42 45 5 41 | 768497.9210 | 76 | 100 | c | 42 9 33 43 8 36 | 24319.6578 | 0 | 1 | b |
| 47 4 44 46 5 41 | 76539.9912 | -4 | 2 | a | 44 7 37 43 8 36 | 111875.5411 | 0 | 2 | a |
| 49 4 46 48 5 43 | 24915.7487 | 0 | 1 | b | 45 7 39 44 8 36 | 128103.8100 | -23 | 80 | |
| 9 7 3 8 6 2 | 835294.8380 | -90 | 100 | c | 46 7 39 45 8 38 | 158845.0800 | 10 | 80 | |
| 11 7 5 10 6 4 | 873600.7260 | 127 | 100 | c | 48 7 41 47 8 40 | 208302.8000 | -9 | 150 | |
| 12 7 5 11 6 6 | 892745.9050 | -394 | 100 | c | 49 7 43 48 8 40 | 213703.0000 | -18 | 150 | |
| 18 7 11 19 6 14 | 297782.5700 | -18 | 200 | | 57 7 51 56 8 48 | 368330.6690 | -267 | 90 | d |
| 19 7 13 20 6 14 | 278250.9700 | 2 | 200 | | 10 10 0 10 9 1 | 964551.5430 | 9 | 50 | e |
| 25 7 19 26 6 20 | 159447.9600 | 22 | 80 | | 11 10 2 11 9 3 | 964580.9600 | -59 | 100 | e |
| 26 7 19 27 6 22 | 139474.5400 | 37 | 80 | | 12 10 2 12 9 3 | 964609.4740 | 3 | 60 | e |
| 27 7 21 28 6 22 | 118994.2360 | 3 | 2 | a | 13 10 4 13 9 5 | 964635.9770 | 57 | 80 | e |
| 28 7 21 29 6 24 | 98976.2940 | 0 | 2 | a | 14 10 4 14 9 5 | 964659.3200 | 0 | 50 | e |
| 30 5 25 29 6 24 | 36338.0500 | -57 | 30 | | 15 10 6 15 9 7 | 964678.5440 | -1 | 50 | e |
| 29 7 23 30 6 24 | 77926.7070 | -1 | 2 | a | 16 10 6 16 9 7 | 964692.3890 | 0 | 80 | e |
| 31 5 27 30 6 24 | 47660.6000 | -21 | 50 | | 17 10 8 18 9 9 | 619888.4240 | 44 | 100 | c |
| 30 7 23 31 6 26 | 58042.4100 | -229 | 200 | | 19 10 10 19 9 11 | 964688.3580 | -14 | 80 | e |
| 31 7 25 32 6 26 | 36065.2300 | -48 | 30 | | 20 10 10 20 9 11 | 964667.0150 | -13 | 40 | e |
| 33 5 29 32 6 26 | 87926.2739 | 0 | 2 | a | 21 10 12 21 9 13 | 964633.0160 | -51 | 80 | e |
| 34 5 29 33 6 28 | 135963.0000 | -25 | 80 | | 22 10 12 22 9 13 | 964584.7990 | 0 | 100 | e |
| 32 7 25 33 6 28 | 16681.0300 | 8 | 100 | | 25 10 16 25 9 17 | 964335.9680 | -21 | 50 | |
| 35 5 31 34 6 28 | 126980.7000 | -1 | 80 | | 26 10 16 26 9 17 | 964211.8700 | -34 | 50 | e |
| 36 5 31 35 6 30 | 192236.1800 | 23 | 100 | | 27 10 18 27 9 19 | 964063.7520 | -37 | 50 | e |
| 42 7 35 42 6 36 | 614113.6820 | 86 | 100 | c | 28 10 18 28 9 19 | 963889.3900 | -35 | 50 | e |
| 48 7 41 48 6 42 | 555750.3340 | 43 | 100 | c | 29 10 20 29 9 21 | 963686.4940 | -36 | 50 | e |
| 50 7 43 50 6 44 | 529606.8820 | -21 | 100 | c | 30 10 20 30 9 21 | 963452.6120 | -48 | 50 | e |
| 53 5 49 52 6 46 | 209874.3700 | -11 | 150 | | 31 10 22 31 9 23 | 963185.3650 | -32 | 50 | e |
| 51 9 43 52 6 46 | 1020137.0930 | -17 | 100 | e | 32 10 22 32 9 23 | 962881.9580 | -33 | 80 | e |
| 54 7 47 54 6 48 | 476625.5430 | 12 | 100 | c | 33 10 24 33 9 25 | 962539.9630 | -29 | 140 | e |
| 56 7 49 56 6 50 | 455093.0980 | -65 | 100 | c | 33 10 24 34 9 25 | 310017.1960 | -17 | 120 | d |
| 57 5 53 56 6 50 | 115904.9387 | 0 | 2 | a | 34 10 24 34 9 25 | 962156.0980 | -24 | 230 | e |
| 57 7 51 57 6 52 | 667419.8370 | -154 | 100 | c | 34 10 24 35 9 27 | 290338.5420 | -67 | 120 | d |
| 59 5 55 58 6 52 | 56572.0000 | -161 | 50 | | 35 10 26 35 9 27 | 961728.1900 | -24 | 380 | e |
| 9 8 2 10 7 3 | 572554.2690 | 31 | 40 | e | 36 10 26 36 9 27 | 961251.8830 | -20 | 630 | e |
| 14 8 6 15 7 9 | 476621.5470 | 18 | 100 | c | 36 10 26 37 9 29 | 250816.7080 | -85 | 120 | d |
| 24 8 16 25 7 19 | 282636.2400 | 26 | 200 | | 38 10 28 39 9 31 | 211053.1000 | -13 | 150 | |
| 27 8 20 28 7 21 | 223434.4700 | -26 | 150 | | 39 10 30 40 9 31 | 191067.2300 | 78 | 100 | |
| 28 8 20 29 7 23 | 203570.1500 | 47 | 100 | | 40 10 30 40 9 31 | 958804.9540 | -4 | 60 | e |
| 29 8 22 30 7 23 | 183582.7100 | -25 | 100 | | 41 10 32 41 9 33 | 958045.4380 | 0 | 60 | e |

to 50 kHz. Frequency shifts of the spectral line produced by the gas pressure have neither been estimated nor taken into account. Occasional superposition of lines belonging to other vibrational states or other isotopic combinations of the $SO_2$ molecule is also possible and may yield errors up to 1 MHz. Those isolated cases were revealed during the fitting

**TABLE 1**—*Continued*

| Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| 41 10 32 42 9 33 | 150878.8100 | -7 | 80 | | 55 10 46 54 11 43 | 9240.7370 | 37 | 40 | b |
| 42 10 32 42 9 33 | 957203.8310 | 0 | 50 | e | 56 10 46 55 11 45 | 30218.8400 | 96 | 100 | |
| 42 10 32 43 9 35 | 130680.0100 | 27 | 80 | | 54 12 42 55 11 45 | 97177.2731 | 0 | 2 | a |
| 43 10 34 43 9 35 | 956308.7530 | 5 | 50 | e | 57 10 48 56 11 45 | 51086.1000 | -100 | 100 | |
| 45 8 38 44 9 35 | 17539.9400 | 0 | 100 | | 55 12 44 56 11 45 | 76860.5500 | -14 | 50 | |
| 43 10 34 44 9 35 | 110363.8000 | -40 | 80 | | 56 12 44 57 11 47 | 56481.3007 | 0 | 2 | a |
| 44 10 34 44 9 35 | 955306.2220 | 6 | 50 | e | 58 10 48 57 11 47 | 72383.6912 | 0 | 2 | a |
| 45 10 36 45 9 37 | 954265.6690 | 9 | 50 | | 59 10 50 58 11 47 | 93372.9528 | 0 | 2 | a |
| 46 8 38 45 9 37 | 39446.9900 | -16 | 100 | | 57 12 46 58 11 47 | 36003.5400 | -6 | 100 | |
| 44 10 34 45 9 37 | 90005.1263 | -2 | 2 | a | 60 10 50 59 11 49 | 115090.7045 | -4 | 2 | a |
| 46 10 36 46 9 37 | 953072.6190 | 8 | 80 | | 58 12 46 59 11 49 | 15470.4000 | -30 | 100 | |
| 45 10 36 46 9 37 | 69480.4355 | 0 | 2 | a | 69 10 60 68 11 57 | 311975.7870 | 218 | 270 | d |
| 47 8 40 46 9 37 | 59883.5317 | 1 | 2 | a | 35 13 23 36 12 24 | 571775.1540 | -43 | 100 | c |
| 46 10 36 47 9 39 | 48958.1800 | -39 | 30 | | 37 13 25 38 12 26 | 533208.7860 | -49 | 100 | c |
| 47 10 38 47 9 39 | 951882.3790 | 8 | 60 | | 40 13 27 41 12 30 | 475196.4760 | -11 | 100 | c |
| 48 10 38 48 9 39 | 950456.6180 | 6 | 60 | | 41 13 29 42 12 30 | 455809.9620 | -56 | 100 | c |
| 47 10 38 48 9 39 | 28179.2000 | -115 | 50 | | 53 13 41 54 12 42 | 220597.1400 | 122 | 150 | |
| 49 8 42 48 9 39 | 102707.2523 | 2 | 2 | a | 57 13 45 58 12 46 | 140800.1600 | -1 | 80 | |
| 48 10 38 49 9 41 | 7503.4400 | 1 | 1 | b | 60 11 49 59 12 48 | 5189.2450 | 0 | 1 | b |
| 50 8 42 49 9 41 | 127081.9600 | -3 | 80 | | 59 13 47 60 12 48 | 100563.0067 | 2 | 2 | a |
| 51 8 44 50 9 41 | 145970.2900 | 35 | 80 | | 61 11 51 60 12 48 | 25883.6000 | -4 | 200 | |
| 53 8 46 52 9 43 | 189575.3000 | -220 | 100 | | 62 11 51 61 12 50 | 46752.9000 | -7 | 200 | |
| 54 8 46 53 9 45 | 220102.6800 | 56 | 150 | | 61 13 49 62 12 50 | 60072.5800 | -48 | 50 | |
| 55 8 48 54 9 45 | 233345.4300 | -59 | 120 | d | 62 13 49 63 12 52 | 39730.0000 | -107 | 200 | |
| 57 8 50 56 9 47 | 276992.8400 | -60 | 200 | | 63 13 51 64 12 52 | 19306.2000 | -14 | 200 | |
| 61 8 54 60 9 51 | 362022.9670 | -112 | 150 | d | 65 11 55 64 12 52 | 109740.4069 | 6 | 2 | a |
| 15 11 5 15 10 6 | 1064205.9960 | 0 | 150 | e | 15 14 2 16 13 3 | 1052274.1380 | 16 | 90 | e |
| 16 11 5 16 10 6 | 1064241.1400 | 2 | 150 | e | 16 14 2 17 13 5 | 1033183.1890 | 22 | 50 | e |
| 17 11 7 17 10 8 | 1064272.2890 | -637 | 150 | e | 17 14 4 18 13 5 | 1014093.8480 | 117 | 150 | e |
| 18 11 7 18 10 8 | 1064300.3540 | -4 | 150 | e | 18 14 4 19 13 7 | 995005.3280 | 16 | 100 | e |
| 19 11 9 19 10 10 | 1064322.3580 | -11 | 50 | e | 33 14 20 34 13 21 | 708381.1450 | -45 | 100 | c |
| 20 11 9 20 10 10 | 1064337.8360 | -2 | 80 | e | 35 14 22 36 13 23 | 670047.1990 | 61 | 100 | c |
| 23 11 13 23 10 14 | 1064333.4250 | 529 | 300 | e | 40 14 26 41 13 29 | 573977.5280 | 103 | 100 | c |
| 24 11 13 24 10 14 | 1064309.7810 | -22 | 50 | e | 42 14 28 43 13 31 | 535433.8770 | 79 | 100 | c |
| 26 11 15 26 10 16 | 1064223.0250 | -15 | 150 | e | 43 14 30 44 13 31 | 516132.7280 | -1 | 100 | c |
| 30 11 19 31 10 22 | 469422.3430 | -11 | 100 | c | 45 14 32 46 13 33 | 477466.1790 | 25 | 100 | c |
| 34 11 23 34 10 24 | 1063097.5450 | -9 | 50 | e | 46 14 32 47 13 35 | 458098.1930 | 11 | 100 | c |
| 35 11 25 35 10 26 | 1062839.3820 | -3 | 60 | e | 51 14 38 52 13 39 | 360859.1960 | -27 | 150 | d |
| 36 11 25 36 10 26 | 1062548.3730 | 22 | 50 | e | 66 12 54 65 13 53 | 21761.4000 | 52 | 200 | |
| 37 11 27 37 10 28 | 1062222.2880 | 3 | 50 | e | 64 14 50 65 13 53 | 103807.6172 | -1 | 2 | a |
| 38 11 27 38 10 28 | 1061858.7830 | 7 | 50 | e | 67 12 56 66 13 53 | 42397.7000 | 100 | 200 | |
| 37 11 27 38 10 28 | 333043.3430 | -108 | 180 | d | 67 14 54 68 13 55 | 43321.7000 | -8 | 200 | |
| 39 11 29 39 10 30 | 1061455.6230 | 10 | 90 | e | 68 14 54 69 13 57 | 23041.1000 | -47 | 200 | |
| 39 11 29 40 10 30 | 293717.6990 | -105 | 120 | d | 70 12 58 69 13 57 | 104915.5817 | -2 | 2 | a |
| 40 11 29 40 10 30 | 1061010.0250 | 14 | 150 | e | 20 15 5 21 14 8 | 1053599.8820 | 5 | 80 | e |
| 40 11 30 41 10 31 | 273982.6070 | 216 | 90 | d | 21 15 7 22 14 8 | 1034528.1280 | 6 | 50 | e |
| 41 11 31 41 10 32 | 1060519.9160 | 18 | 240 | e | 43 15 29 44 14 30 | 614155.8150 | 112 | 100 | c |
| 42 11 31 42 10 32 | 1059981.8100 | 25 | 390 | e | 57 15 43 58 14 44 | 343476.7110 | 25 | 90 | d |
| 42 11 31 43 10 34 | 234353.0140 | -5 | 150 | d | 71 13 59 70 14 56 | 17719.1500 | 301 | 100 | |
| 43 11 33 43 10 34 | 1059394.2300 | 19 | 610 | e | 72 15 57 73 14 60 | 46786.9000 | -266 | 200 | |
| 44 11 33 44 10 34 | 1058752.2310 | 29 | 957 | e | 73 15 59 74 14 60 | 26644.5000 | -143 | 200 | |
| 43 11 33 44 10 34 | 214451.8900 | 54 | 150 | | 25 16 10 26 15 11 | 1054291.5550 | -15 | 80 | e |
| 44 11 33 45 10 36 | 194491.7500 | 78 | 100 | | 26 16 10 27 15 13 | 1035242.7450 | -11 | 50 | e |
| 46 11 35 46 10 36 | 1057297.5160 | 25 | 50 | e | 27 16 12 28 15 13 | 1016194.6570 | -2 | 70 | e |
| 47 11 37 47 10 38 | 1056481.1610 | 25 | 50 | e | 30 16 14 31 15 17 | 959049.9840 | -11 | 70 | e |
| 46 11 35 47 10 38 | 154373.3400 | 1 | 80 | | 33 16 18 34 15 19 | 901894.2820 | 3 | 80 | e |
| 47 11 37 48 10 38 | 134203.8200 | -20 | 80 | | 45 16 30 46 15 31 | 672850.7520 | 68 | 100 | c |
| 49 11 39 49 10 40 | 1054643.4680 | 17 | 80 | e | 55 16 40 56 15 41 | 480838.3050 | 229 | 100 | c |
| 50 9 41 49 10 40 | 13599.5000 | -99 | 100 | | 56 16 40 57 15 43 | 461546.3560 | 163 | 100 | c |
| 48 11 37 49 10 40 | 113970.8732 | -3 | 2 | a | 57 16 42 58 15 43 | 442234.4750 | 247 | 100 | c |
| 51 9 43 50 10 40 | 34393.5500 | -12 | 100 | | 30 17 13 31 16 16 | 1054347.5720 | -30 | 80 | e |
| 50 11 39 51 10 42 | 73255.2170 | 1 | 2 | a | 31 17 15 32 16 16 | 1035326.6470 | -11 | 50 | e |
| 52 9 43 51 10 42 | 55932.0000 | -220 | 100 | | 32 17 15 33 16 18 | 1016306.4350 | 0 | 80 | e |
| 53 9 45 52 10 42 | 76762.2882 | 5 | 2 | a | 45 17 29 46 16 30 | 768898.3130 | 4 | 100 | c |
| 51 11 41 52 10 42 | 52744.0000 | -127 | 100 | | 35 18 18 36 17 19 | 1053771.5790 | -26 | 80 | e |
| 54 9 45 53 10 44 | 98917.8393 | 0 | 2 | a | 36 18 18 37 17 21 | 1034784.3430 | 11 | 50 | e |
| 52 11 41 53 10 44 | 32195.4500 | -15 | 100 | | 37 18 20 38 17 21 | 1015798.1420 | 131 | 150 | e |
| 53 11 43 54 10 44 | 11472.3380 | 7 | 2 | a | 43 18 26 44 17 27 | 901877.9040 | 240 | 100 | e |
| 56 9 47 55 10 46 | 142690.1800 | 13 | 80 | | 40 19 21 41 18 24 | 1052570.8420 | -7 | 90 | e |
| 59 9 51 58 10 48 | 206786.9920 | 50 | 60 | d | 41 19 23 42 18 24 | 1033623.7010 | 54 | 50 | e |
| 63 9 55 62 10 52 | 295433.0760 | -257 | 150 | d | 42 19 23 43 18 26 | 1014678.0950 | 269 | 200 | e |
| 65 9 57 64 10 54 | 339890.9380 | -26 | 90 | d | 44 20 24 45 19 27 | 1069657.6350 | -91 | 50 | e |
| 22 12 10 23 11 13 | 722704.8710 | -23 | 100 | c | 45 20 26 46 19 27 | 1050755.1140 | 18 | 100 | e |
| 30 12 18 31 11 21 | 569102.7840 | 127 | 100 | c | 46 20 26 47 19 29 | 1031854.8740 | 127 | 100 | e |
| 35 12 24 36 11 25 | 472520.7820 | 117 | 100 | c | 47 20 28 48 19 29 | 1012956.6130 | 239 | 200 | e |
| 41 12 30 42 11 31 | 355705.4930 | -16 | 90 | d | 49 21 29 50 20 30 | 1067185.1060 | -172 | 50 | e |
| 45 12 34 46 11 35 | 277085.9600 | 22 | 200 | | 50 21 29 51 20 32 | 1048335.8080 | 8 | 150 | e |
| 49 12 38 50 11 39 | 197709.4500 | 69 | 100 | | 51 21 31 52 20 32 | 1029489.4850 | 188 | 150 | e |
| 52 12 40 53 11 43 | 137585.0500 | 85 | 80 | | 52 21 31 53 20 34 | 1010645.8810 | 384 | 250 | e |
| 53 12 42 54 11 43 | 117412.6120 | -3 | 2 | a | 56 22 34 57 21 37 | 1026540.1510 | 191 | 100 | e |

procedure and were subsequently discarded. In the fittings, about 0.25% of the high frequency line deviations were 4.5 times or greater than the estimated experimental uncertainty. This was probably due to overlapping with hot band or isotopic species. Since the deviations were not systematic, these lines were not included in the final fittings.

## TABLE 2
### Observed Pure Rotational Transitions of $^{34}SO_2$

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 67750.2980 | 0 | 2 | a | 17 | 2 | 16 | 16 | 3 | 13 | 33212.8100 | 3 | 50 | |
| 3 | 1 | 3 | 2 | 0 | 2 | 102031.8784 | -2 | 1000 | | 16 | 4 | 12 | 16 | 3 | 13 | 332836.2250 | -14 | 100 | |
| 1 | 1 | 1 | 2 | 0 | 2 | 10547.8630 | 0 | 1 | f | 15 | 4 | 12 | 16 | 3 | 13 | 25171.0400 | 21 | 50 | |
| 2 | 1 | 1 | 2 | 0 | 2 | 51822.0900 | 215 | 100 | | 17 | 4 | 14 | 17 | 3 | 15 | 345929.3490 | 53 | 100 | |
| 5 | 1 | 5 | 4 | 0 | 4 | 133471.4700 | 39 | 100 | | 16 | 4 | 12 | 17 | 3 | 15 | 20548.1900 | 21 | 50 | |
| 4 | 1 | 3 | 4 | 0 | 4 | 57687.5330 | -7 | 2 | a | 19 | 2 | 18 | 18 | 3 | 15 | 45079.6800 | -53 | 100 | |
| 6 | 1 | 5 | 6 | 0 | 6 | 67768.7795 | -1 | 2 | a | 21 | 2 | 20 | 20 | 3 | 17 | 47293.1100 | -59 | 100 | |
| 9 | 1 | 9 | 8 | 0 | 8 | 191013.3900 | 78 | 100 | | 21 | 4 | 18 | 21 | 3 | 19 | 352082.9210 | 18 | 100 | |
| 8 | 1 | 7 | 8 | 0 | 8 | 83043.8240 | 2 | 2 | a | 23 | 2 | 22 | 22 | 3 | 19 | 39024.1000 | -136 | 100 | |
| 10 | 1 | 9 | 10 | 0 | 10 | 104391.7061 | 0 | 2 | a | 25 | 2 | 24 | 24 | 3 | 21 | 20260.8000 | -10 | 100 | |
| 12 | 1 | 11 | 12 | 0 | 12 | 132114.0400 | -12 | 100 | | 25 | 4 | 22 | 25 | 3 | 23 | 367369.2990 | 40 | 100 | |
| 13 | 1 | 13 | 12 | 0 | 12 | 248698.6040 | -96 | 100 | d | 27 | 4 | 24 | 27 | 3 | 25 | 379498.6180 | 16 | 100 | |
| 16 | 1 | 15 | 16 | 0 | 16 | 203504.2690 | 51 | 100 | d | 30 | 4 | 26 | 30 | 3 | 27 | 249099.3520 | 138 | 100 | d |
| 18 | 1 | 17 | 18 | 0 | 18 | 243936.0520 | 87 | 100 | d | 38 | 4 | 34 | 38 | 3 | 35 | 315193.2590 | 48 | 100 | d |
| 18 | 3 | 15 | 18 | 0 | 18 | 599550.5840 | 7 | 100 | | 44 | 4 | 40 | 44 | 3 | 41 | 447981.1980 | 31 | 100 | c |
| 25 | 1 | 25 | 24 | 0 | 24 | 447275.2490 | -9 | 100 | c | 46 | 4 | 42 | 46 | 3 | 43 | 498409.9990 | 18 | 100 | c |
| 30 | 1 | 29 | 30 | 0 | 30 | 479152.2730 | 69 | 100 | c | 48 | 4 | 44 | 48 | 3 | 45 | 548333.6130 | -21 | 100 | c |
| 34 | 1 | 33 | 34 | 0 | 34 | 551699.8710 | 104 | 100 | c | 55 | 4 | 52 | 54 | 3 | 51 | 1025770.0150 | 38 | 50 | e |
| 37 | 1 | 37 | 36 | 0 | 36 | 656549.4960 | -130 | 100 | c | 6 | 5 | 1 | 5 | 4 | 2 | 558717.5490 | 16 | 100 | c |
| 40 | 1 | 39 | 40 | 0 | 40 | 658797.5170 | 125 | 100 | c | 9 | 5 | 5 | 8 | 4 | 4 | 615985.5290 | 128 | 100 | c |
| 3 | 2 | 2 | 2 | 1 | 1 | 203225.1400 | 78 | 100 | | 7 | 5 | 3 | 8 | 4 | 4 | 291146.2270 | 242 | 100 | d |
| 4 | 0 | 4 | 3 | 1 | 3 | 31011.1800 | 32 | 50 | | 11 | 5 | 7 | 10 | 4 | 6 | 654069.8810 | -64 | 100 | c |
| 2 | 2 | 0 | 3 | 1 | 3 | 95810.4135 | 0 | 2 | a | 14 | 5 | 9 | 13 | 4 | 10 | 711021.0600 | 140 | 100 | c |
| 4 | 2 | 2 | 4 | 1 | 3 | 141158.7600 | -181 | 100 | | 17 | 5 | 13 | 16 | 4 | 12 | 766772.8350 | -51 | 100 | c |
| 6 | 0 | 6 | 5 | 1 | 5 | 74404.5793 | 1 | 2 | a | 18 | 3 | 15 | 17 | 4 | 14 | 23732.9900 | -1 | 50 | |
| 5 | 2 | 4 | 6 | 1 | 5 | 17970.4200 | 165 | 100 | | 16 | 5 | 11 | 17 | 4 | 14 | 115744.6662 | 0 | 2 | a |
| 6 | 2 | 4 | 6 | 1 | 5 | 134826.1200 | -129 | 100 | | 19 | 3 | 17 | 18 | 4 | 14 | 14754.7000 | -46 | 50 | |
| 8 | 2 | 6 | 7 | 1 | 7 | 330191.1030 | -56 | 100 | | 17 | 5 | 13 | 18 | 4 | 14 | 93852.0657 | 0 | 2 | a |
| 8 | 0 | 8 | 7 | 1 | 7 | 118478.5480 | 2 | 2 | a | 20 | 3 | 17 | 19 | 4 | 16 | 77231.3753 | 1 | 2 | a |
| 6 | 2 | 4 | 7 | 1 | 7 | 39819.2000 | 52 | 100 | | 18 | 5 | 13 | 19 | 4 | 16 | 76031.2305 | 1 | 2 | a |
| 8 | 2 | 6 | 9 | 1 | 9 | 20699.2600 | -42 | 50 | | 21 | 3 | 19 | 20 | 4 | 16 | 47002.3400 | -31 | 59 | |
| 10 | 2 | 8 | 11 | 1 | 11 | 9650.6300 | -156 | 50 | | 22 | 3 | 19 | 21 | 4 | 18 | 135566.2800 | -5 | 200 | |
| 11 | 2 | 10 | 11 | 1 | 11 | 201376.4170 | -70 | 100 | d | 20 | 5 | 15 | 21 | 4 | 18 | 36294.5400 | -4 | 50 | |
| 14 | 2 | 12 | 14 | 1 | 13 | 129803.3600 | -34 | 100 | | 23 | 3 | 21 | 22 | 4 | 18 | 74698.1706 | 1 | 2 | a |
| 15 | 2 | 14 | 15 | 1 | 15 | 245178.5870 | -143 | 100 | d | 24 | 3 | 21 | 23 | 4 | 20 | 198348.5400 | 23 | 100 | |
| 14 | 2 | 12 | 15 | 1 | 15 | 15994.1000 | -41 | 100 | | 25 | 3 | 23 | 24 | 4 | 20 | 96075.2978 | -1 | 2 | a |
| 16 | 2 | 14 | 16 | 1 | 15 | 141653.1600 | -246 | 100 | | 26 | 3 | 23 | 25 | 4 | 22 | 264682.7600 | -138 | 100 | d |
| 16 | 2 | 14 | 17 | 1 | 17 | 33672.1000 | -136 | 100 | | 27 | 3 | 25 | 26 | 4 | 22 | 109260.5100 | 1 | 2 | a |
| 21 | 2 | 20 | 21 | 1 | 21 | 330667.5650 | -202 | 100 | | 29 | 3 | 27 | 28 | 4 | 24 | 112577.8993 | 0 | 2 | a |
| 20 | 2 | 18 | 21 | 1 | 21 | 94250.8406 | 0 | 2 | a | 31 | 3 | 29 | 30 | 4 | 26 | 104914.6988 | 0 | 2 | a |
| 24 | 2 | 22 | 23 | 1 | 23 | 1054659.4890 | -8 | 80 | e | 38 | 5 | 33 | 38 | 4 | 34 | 310375.9900 | 89 | 100 | d |
| 23 | 2 | 22 | 23 | 1 | 23 | 362834.0860 | -91 | 100 | | 44 | 5 | 39 | 44 | 4 | 40 | 330519.2370 | 150 | 100 | |
| 24 | 2 | 22 | 24 | 1 | 23 | 260326.9970 | 45 | 100 | d | 6 | 6 | 0 | 5 | 5 | 1 | 656900.7130 | -3 | 100 | c |
| 28 | 0 | 28 | 27 | 1 | 27 | 498995.0360 | 42 | 100 | c | 6 | 6 | 0 | 6 | 5 | 1 | 542302.2310 | -59 | 60 | e |
| 28 | 2 | 26 | 28 | 1 | 27 | 347483.1240 | 104 | 100 | | 7 | 6 | 2 | 7 | 5 | 3 | 542291.7170 | -63 | 50 | e |
| 31 | 2 | 30 | 30 | 1 | 29 | 572591.3100 | -88 | 300 | e | 9 | 6 | 4 | 8 | 5 | 3 | 714223.7010 | -93 | 100 | c |
| 34 | 0 | 34 | 33 | 1 | 33 | 604080.0040 | -9 | 100 | c | 8 | 6 | 2 | 8 | 5 | 3 | 542270.0660 | -59 | 50 | e |
| 35 | 2 | 34 | 35 | 1 | 35 | 570537.9420 | 29 | 300 | e | 8 | 6 | 2 | 9 | 5 | 5 | 370280.0080 | 133 | 100 | |
| 37 | 2 | 36 | 37 | 1 | 37 | 605924.4030 | -104 | 100 | c | 9 | 6 | 4 | 9 | 5 | 5 | 542233.4830 | -61 | 80 | e |
| 7 | 3 | 5 | 7 | 2 | 6 | 248364.7630 | -7 | 100 | d | 10 | 6 | 4 | 10 | 5 | 5 | 542177.3740 | -63 | 220 | e |
| 6 | 3 | 3 | 7 | 2 | 6 | 114574.4390 | 3 | 2 | a | 11 | 6 | 6 | 11 | 5 | 7 | 542097.6450 | -52 | 589 | e |
| 8 | 1 | 7 | 7 | 2 | 6 | 30975.4500 | 36 | 50 | | 13 | 6 | 8 | 14 | 5 | 9 | 273930.1000 | 117 | 100 | d |
| 8 | 3 | 5 | 9 | 2 | 8 | 78397.0175 | 0 | 2 | a | 21 | 6 | 16 | 22 | 5 | 17 | 115722.1453 | -3 | 2 | a |
| 10 | 1 | 9 | 9 | 2 | 8 | 82124.3470 | 0 | 2 | a | 22 | 6 | 16 | 23 | 5 | 19 | 96193.8592 | 2 | 2 | a |
| 9 | 3 | 7 | 9 | 2 | 8 | 250358.4930 | 107 | 100 | d | 24 | 4 | 20 | 23 | 5 | 19 | 40652.4200 | 16 | 50 | |
| 9 | 3 | 7 | 10 | 2 | 8 | 43619.9100 | -34 | 100 | | 25 | 4 | 22 | 24 | 5 | 19 | 41540.9000 | 4 | 50 | |
| 10 | 3 | 7 | 11 | 2 | 10 | 44226.2400 | 17 | 100 | | 23 | 6 | 18 | 24 | 5 | 19 | 74580.7642 | 2 | 2 | a |
| 12 | 1 | 11 | 11 | 2 | 10 | 134873.8400 | 42 | 100 | | 26 | 4 | 22 | 25 | 5 | 21 | 92428.8728 | 1 | 2 | a |
| 12 | 3 | 9 | 13 | 2 | 12 | 13207.9000 | -105 | 100 | | 25 | 6 | 20 | 26 | 5 | 21 | 32272.3400 | -59 | 50 | |
| 14 | 3 | 11 | 14 | 2 | 12 | 215999.6550 | -80 | 100 | d | 26 | 6 | 20 | 27 | 5 | 23 | 14850.4000 | -37 | 100 | |
| 17 | 3 | 15 | 17 | 2 | 16 | 279075.1980 | -66 | 100 | d | 29 | 4 | 26 | 28 | 5 | 23 | 111902.7923 | -2 | 2 | a |
| 18 | 3 | 15 | 17 | 2 | 16 | 648737.5970 | 46 | 100 | c | 34 | 4 | 30 | 33 | 5 | 29 | 350619.3300 | -154 | 100 | |
| 18 | 3 | 15 | 18 | 2 | 16 | 194812.0600 | 23 | 100 | | 36 | 6 | 30 | 36 | 5 | 31 | 480055.4370 | 41 | 100 | c |
| 20 | 3 | 17 | 20 | 2 | 18 | 189123.8900 | 133 | 100 | | 37 | 4 | 34 | 36 | 5 | 31 | 184532.8070 | -139 | 100 | d |
| 22 | 3 | 19 | 22 | 2 | 20 | 189392.4560 | 106 | 100 | d | 38 | 4 | 34 | 37 | 5 | 33 | 501920.1460 | 40 | 100 | c |
| 25 | 3 | 23 | 24 | 2 | 22 | 573527.2090 | -98 | 300 | | 38 | 6 | 32 | 38 | 5 | 33 | 459535.9110 | 41 | 100 | c |
| 24 | 3 | 21 | 24 | 2 | 22 | 197044.3000 | 190 | 100 | | 37 | 8 | 30 | 38 | 5 | 33 | 1060418.9610 | -30 | 250 | e |
| 25 | 3 | 23 | 25 | 2 | 24 | 356222.2500 | -136 | 100 | | 42 | 4 | 38 | 41 | 5 | 37 | 652745.7910 | 202 | 100 | |
| 30 | 3 | 27 | 30 | 2 | 28 | 270229.5550 | -124 | 100 | d | 42 | 4 | 38 | 41 | 5 | 37 | 652745.5610 | -27 | 50 | c |
| 32 | 3 | 29 | 32 | 2 | 30 | 309816.0170 | 52 | 100 | d | 43 | 6 | 38 | 43 | 5 | 39 | 542257.6730 | -101 | 100 | c |
| 38 | 3 | 35 | 38 | 2 | 36 | 448811.0480 | 57 | 100 | c | 45 | 6 | 40 | 45 | 5 | 41 | 553329.1380 | -56 | 100 | c |
| 40 | 3 | 37 | 40 | 2 | 38 | 495286.9690 | -36 | 100 | c | 46 | 6 | 40 | 46 | 5 | 41 | 374322.5310 | -91 | 100 | |
| 5 | 4 | 2 | 4 | 3 | 1 | 441174.0320 | -3 | 100 | c | 48 | 6 | 42 | 48 | 5 | 43 | 365141.1440 | 262 | 100 | |
| 11 | 4 | 8 | 12 | 3 | 9 | 112532.3159 | -2 | 2 | a | 7 | 7 | 1 | 6 | 6 | 0 | 773885.7200 | -82 | 100 | c |
| 12 | 4 | 8 | 13 | 3 | 11 | 95922.8159 | 0 | 2 | a | 9 | 7 | 3 | 10 | 6 | 4 | 449079.3570 | 51 | 100 | c |
| 14 | 2 | 12 | 13 | 3 | 11 | 58552.7177 | 0 | 2 | a | 15 | 7 | 9 | 16 | 6 | 10 | 333683.9180 | 24 | 100 | |
| 14 | 4 | 10 | 13 | 3 | 11 | 613338.1480 | 0 | 100 | c | 22 | 7 | 15 | 23 | 6 | 18 | 196854.5610 | 101 | 100 | d |
| 15 | 2 | 14 | 14 | 3 | 11 | 13184.8000 | -53 | 100 | | 28 | 5 | 23 | 27 | 6 | 22 | 11695.0500 | -28 | 100 | |
| 16 | 4 | 12 | 15 | 3 | 13 | 652652.8650 | 50 | 100 | | 27 | 7 | 21 | 28 | 6 | 22 | 96204.0652 | 0 | 2 | a |
| 16 | 2 | 14 | 15 | 3 | 13 | 115291.3883 | 0 | 2 | a | 29 | 5 | 25 | 28 | 6 | 22 | 26038.3500 | 84 | 50 | |

[a] Alekseev *et al.*

[c] Helminger and deLucia.

[d] Measurements taken at Nizhni Novgorod.

[e] Measurements taken at Cologne.

[f] NIST measurement.

All other frequencies are from the compilation of Lovas.

**TABLE 2**—*Continued*

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | 7 | 21 | 29 | 6 | 24 | 76220.1176 | 3 | 2 | a | 44 | 8 | 36 | 43 | 9 | 35 | 27657.1500 | -54 | 50 | |
| 30 | 7 | 23 | 31 | 6 | 26 | 35126.5600 | 12 | 50 | | 45 | 10 | 36 | 46 | 9 | 37 | 35905.6000 | -108 | 100 | |
| 32 | 5 | 27 | 31 | 6 | 26 | 107567.8420 | -1 | 2 | a | 48 | 8 | 40 | 47 | 9 | 39 | 114706.6849 | -2 | 2 | a |
| 31 | 7 | 25 | 32 | 6 | 26 | 12567.3000 | -41 | 100 | | 11 | 11 | 1 | 11 | 10 | 2 | 1027561.3930 | 17 | 100 | e |
| 33 | 5 | 29 | 32 | 6 | 26 | 106374.2560 | -5 | 200 | | 12 | 11 | 1 | 12 | 10 | 2 | 1027597.1520 | 151 | 150 | e |
| 38 | 7 | 31 | 38 | 6 | 32 | 608339.1530 | 37 | 100 | c | 13 | 11 | 3 | 13 | 10 | 4 | 1027632.2750 | 193 | 150 | e |
| 39 | 5 | 35 | 38 | 6 | 32 | 210817.3770 | -199 | 100 | d | 14 | 11 | 3 | 14 | 10 | 4 | 1027665.7700 | -10 | 60 | e |
| 41 | 5 | 37 | 40 | 6 | 34 | 236023.1670 | -99 | 100 | d | 15 | 11 | 5 | 15 | 10 | 6 | 1027696.5280 | -663 | 1000 | e |
| 40 | 7 | 33 | 40 | 6 | 34 | 597519.2310 | -209 | 100 | c | 16 | 11 | 5 | 16 | 10 | 6 | 1027725.3330 | -14 | 60 | e |
| 43 | 7 | 37 | 43 | 6 | 38 | 612670.9680 | 146 | 100 | c | 17 | 11 | 7 | 17 | 10 | 8 | 1027749.1990 | -18 | 60 | e |
| 46 | 7 | 39 | 46 | 6 | 40 | 542984.6260 | -77 | 100 | c | 18 | 11 | 7 | 18 | 10 | 8 | 1027767.6910 | -14 | 70 | e |
| 48 | 7 | 41 | 48 | 6 | 42 | 517525.4700 | 122 | 100 | c | 19 | 11 | 9 | 19 | 10 | 10 | 1027779.2730 | -378 | 689 | e |
| 50 | 7 | 43 | 50 | 6 | 44 | 490440.4740 | -67 | 100 | c | 20 | 11 | 9 | 20 | 10 | 10 | 1027783.8130 | -21 | 70 | e |
| 52 | 7 | 45 | 52 | 6 | 46 | 464237.8450 | 305 | 100 | c | 21 | 11 | 11 | 22 | 10 | 12 | 607030.8120 | -130 | 100 | |
| 54 | 7 | 47 | 54 | 6 | 48 | 441872.6430 | -147 | 100 | c | 22 | 11 | 11 | 22 | 10 | 12 | 1027763.6630 | -29 | 60 | e |
| 19 | 8 | 12 | 20 | 7 | 13 | 354397.7600 | 7 | 100 | | 23 | 11 | 13 | 23 | 10 | 14 | 1027736.5710 | -28 | 60 | e |
| 20 | 8 | 12 | 21 | 7 | 15 | 334996.5730 | 41 | 100 | | 24 | 11 | 13 | 24 | 10 | 14 | 1027696.5280 | 324 | 1000 | e |
| 23 | 8 | 16 | 24 | 7 | 17 | 276483.9770 | -25 | 100 | d | 23 | 11 | 13 | 24 | 10 | 14 | 568662.0600 | -20 | 100 | |
| 34 | 6 | 28 | 33 | 7 | 27 | 30977.3800 | 6 | 50 | | 25 | 11 | 15 | 25 | 10 | 16 | 1027641.1330 | 176 | 150 | e |
| 32 | 8 | 24 | 33 | 7 | 27 | 96987.7343 | 1 | 2 | a | 24 | 11 | 13 | 25 | 10 | 16 | 549451.1410 | 3 | 100 | c |
| 33 | 8 | 26 | 34 | 7 | 27 | 76312.7811 | 0 | 2 | a | 26 | 11 | 15 | 26 | 10 | 16 | 1027569.2130 | -30 | 50 | e |
| 36 | 6 | 30 | 35 | 7 | 29 | 76252.7668 | 1 | 2 | a | 27 | 11 | 17 | 27 | 10 | 18 | 1027479.2620 | -119 | 100 | e |
| 35 | 8 | 28 | 36 | 7 | 29 | 34811.0100 | 70 | 50 | | 28 | 11 | 17 | 28 | 10 | 18 | 1027369.5780 | -39 | 50 | e |
| 37 | 6 | 32 | 36 | 7 | 29 | 90196.8665 | 2 | 2 | a | 33 | 11 | 23 | 33 | 10 | 24 | 1026455.9420 | -23 | 50 | e |
| 36 | 8 | 28 | 37 | 7 | 31 | 14547.1000 | -102 | 50 | | 36 | 11 | 25 | 36 | 10 | 26 | 1025540.8400 | -14 | 50 | e |
| 43 | 6 | 38 | 42 | 7 | 35 | 212385.5920 | -85 | 100 | d | 37 | 11 | 27 | 38 | 10 | 28 | 297158.1490 | -293 | 100 | |
| 44 | 6 | 38 | 43 | 7 | 37 | 290453.7600 | -379 | 100 | d | 39 | 11 | 29 | 39 | 10 | 30 | 1024273.7290 | -11 | 160 | e |
| 45 | 6 | 40 | 44 | 7 | 37 | 249301.2030 | -104 | 100 | d | 42 | 11 | 31 | 42 | 10 | 32 | 1022582.2250 | -5 | 680 | e |
| 51 | 6 | 46 | 50 | 7 | 43 | 330030.1290 | -358 | 100 | d | 43 | 11 | 33 | 43 | 10 | 34 | 1021911.5390 | -1 | 150 | e |
| 51 | 8 | 44 | 51 | 7 | 45 | 698090.3780 | -80 | 50 | e | 44 | 11 | 33 | 44 | 10 | 34 | 1021179.3950 | 3 | 1669 | e |
| 12 | 9 | 3 | 13 | 8 | 6 | 586375.5290 | 29 | 100 | | 45 | 11 | 35 | 45 | 10 | 36 | 1020388.1530 | 9 | 2581 | e |
| 17 | 9 | 9 | 18 | 8 | 10 | 490539.5530 | -82 | 100 | c | 46 | 11 | 35 | 46 | 10 | 36 | 1019525.3600 | -1 | 100 | e |
| 19 | 9 | 11 | 20 | 8 | 12 | 452062.4610 | -30 | 100 | c | 47 | 11 | 37 | 47 | 10 | 38 | 1018601.2520 | 225 | 300 | e |
| 28 | 9 | 19 | 29 | 8 | 22 | 277150.5750 | -23 | 100 | d | 48 | 11 | 37 | 48 | 10 | 38 | 1017590.5510 | 54 | 200 | e |
| 39 | 7 | 33 | 38 | 8 | 30 | 27398.0000 | -6 | 50 | | 49 | 9 | 41 | 48 | 10 | 38 | 26505.4000 | -70 | 50 | |
| 37 | 9 | 29 | 38 | 8 | 30 | 97236.5286 | -1 | 2 | a | 49 | 11 | 39 | 49 | 10 | 40 | 1016521.1670 | 196 | 200 | e |
| 40 | 9 | 31 | 41 | 8 | 34 | 35664.8000 | 10 | 100 | | 53 | 9 | 45 | 52 | 10 | 42 | 111539.3201 | 0 | 2 | a |
| 42 | 7 | 35 | 41 | 8 | 34 | 95242.6137 | 0 | 2 | a | 26 | 12 | 14 | 27 | 11 | 17 | 607007.8760 | 246 | 300 | |
| 41 | 9 | 33 | 42 | 8 | 34 | 14583.0500 | -18 | 50 | | 28 | 12 | 16 | 29 | 11 | 19 | 568601.5350 | -35 | 100 | |
| 43 | 7 | 37 | 42 | 8 | 34 | 112553.5831 | 1 | 2 | a | 29 | 12 | 18 | 30 | 11 | 19 | 549370.6640 | -227 | 100 | |
| 47 | 7 | 41 | 46 | 8 | 38 | 198262.5790 | -52 | 100 | d | 29 | 12 | 18 | 30 | 11 | 19 | 549370.8950 | 3 | 100 | |
| 56 | 7 | 49 | 55 | 8 | 48 | 500228.1230 | 85 | 100 | c | 30 | 12 | 18 | 31 | 11 | 21 | 530119.7540 | 15 | 100 | c |
| 11 | 10 | 2 | 11 | 9 | 3 | 931458.3930 | -108 | 80 | e | 32 | 12 | 20 | 33 | 11 | 23 | 491549.4870 | -87 | 100 | c |
| 12 | 10 | 2 | 12 | 9 | 3 | 931482.5650 | -7 | 40 | e | 31 | 13 | 19 | 32 | 12 | 20 | 606472.2100 | -6 | 100 | |
| 13 | 10 | 4 | 13 | 9 | 5 | 931503.8560 | -29 | 50 | e | 32 | 13 | 19 | 33 | 12 | 22 | 587268.5810 | -2 | 100 | |
| 14 | 10 | 4 | 14 | 9 | 5 | 931521.2810 | -18 | 80 | e | 34 | 13 | 21 | 35 | 12 | 24 | 548807.2150 | -114 | 100 | c |
| 15 | 10 | 6 | 15 | 9 | 7 | 931533.5680 | -18 | 80 | e | 37 | 13 | 25 | 38 | 12 | 26 | 490960.0310 | -66 | 100 | c |
| 16 | 10 | 6 | 16 | 9 | 7 | 931539.4380 | 5 | 80 | e | 14 | 14 | 0 | 15 | 13 | 3 | 1025554.4960 | 105 | 250 | e |
| 16 | 10 | 6 | 17 | 9 | 9 | 606529.7100 | 11 | 100 | | 36 | 14 | 22 | 37 | 13 | 25 | 605440.4280 | 0 | 100 | |
| 17 | 10 | 8 | 17 | 9 | 9 | 931537.2870 | -148 | 80 | e | 37 | 14 | 24 | 38 | 13 | 25 | 586237.5770 | 9 | 300 | |
| 18 | 10 | 8 | 18 | 9 | 9 | 931526.0810 | -23 | 80 | e | 39 | 14 | 26 | 40 | 13 | 27 | 547779.6820 | 315 | 100 | c |
| 19 | 10 | 10 | 19 | 9 | 11 | 931503.8560 | -6 | 50 | e | 42 | 14 | 28 | 43 | 13 | 31 | 489942.9610 | -9 | 100 | c |
| 20 | 10 | 10 | 20 | 9 | 11 | 931469.0190 | -23 | 40 | e | 17 | 15 | 3 | 18 | 14 | 4 | 1061894.1850 | 72 | 120 | e |
| 21 | 10 | 12 | 21 | 9 | 13 | 931419.8630 | -24 | 80 | e | 41 | 15 | 27 | 42 | 14 | 28 | 603928.8160 | 107 | 100 | |
| 22 | 10 | 12 | 22 | 9 | 13 | 931354.5140 | -36 | 80 | e | 47 | 15 | 33 | 48 | 14 | 34 | 488516.1510 | 181 | 100 | c |
| 23 | 10 | 14 | 23 | 9 | 15 | 931271.0580 | -37 | 80 | e | 49 | 15 | 35 | 50 | 14 | 36 | 449884.1550 | 193 | 100 | c |
| 24 | 10 | 14 | 24 | 9 | 15 | 931167.4540 | -34 | 80 | e | 22 | 16 | 6 | 23 | 15 | 9 | 1059489.3900 | 59 | 100 | e |
| 25 | 10 | 16 | 25 | 9 | 17 | 931041.5550 | -50 | 100 | e | 23 | 16 | 8 | 24 | 15 | 9 | 1040461.6080 | 49 | 80 | e |
| 24 | 10 | 14 | 25 | 9 | 17 | 452796.5670 | 27 | 100 | c | 46 | 16 | 30 | 47 | 15 | 33 | 601953.4180 | 381 | 300 | |
| 26 | 10 | 16 | 26 | 9 | 17 | 930891.1760 | -42 | 100 | e | 47 | 16 | 32 | 48 | 15 | 33 | 582784.2600 | 298 | 300 | |
| 29 | 10 | 20 | 30 | 9 | 21 | 355817.8160 | -128 | 100 | | 48 | 16 | 32 | 49 | 15 | 35 | 563600.2250 | 400 | 300 | |
| 30 | 10 | 20 | 31 | 9 | 23 | 336303.6960 | -181 | 100 | | 27 | 17 | 11 | 28 | 16 | 12 | 1056463.1780 | 42 | 80 | e |
| 32 | 10 | 22 | 33 | 9 | 25 | 297133.4780 | 92 | 100 | d | 28 | 17 | 11 | 29 | 16 | 14 | 1037459.0960 | 46 | 80 | e |
| 35 | 10 | 26 | 35 | 9 | 27 | 928016.8910 | -42 | 630 | e | 32 | 18 | 14 | 33 | 17 | 17 | 1052816.9470 | -35 | 180 | e |
| 36 | 10 | 26 | 36 | 9 | 27 | 927474.7850 | -26 | 1040 | e | 33 | 18 | 16 | 34 | 17 | 17 | 1033841.4410 | 18 | 180 | e |
| 38 | 10 | 28 | 38 | 9 | 29 | 926218.5100 | -12 | 200 | e | 36 | 19 | 17 | 37 | 18 | 20 | 1067499.4960 | -195 | 100 | e |
| 40 | 10 | 30 | 40 | 9 | 31 | 924704.8230 | -7 | 120 | e | 59 | 19 | 41 | 60 | 18 | 42 | 631434.3910 | -130 | 100 | |

## III. DERIVATION OF ROTATIONAL CONSTANTS

The high-frequency data measured in this work were combined with all known previous measurements of $SO_2$. Data reported before 1985 have been taken from the compilation of Lovas (*10*). In addition to this data, there have been a number of additional studies including mm-region measurements of Helminger and DeLucia (*11*) and the very high precision measurements mentioned above (*4, 5*) that have also been included in the data set. In order to fix more precisely the higher order distortion terms, we have also included the high $K_a$ transitions measured in the far infrared region by Carlotti *et al.* (*9*). Several low $J$ transitions have also been recorded on the FT microwave instrument at National Institute of Standards and Technology and were included in the fitting. For the $^{32}SO_2$ molecule, the microwave data consisted of 480 transitions including states with $J$ ranging as high as 74 with $K_a$ up to 22.

**TABLE 3**

**Observed Pure Rotational Transitions of $^{32}S^{18}O^{16}O$**

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0 | 0 | 0 | 67430.6000 | 68 | 200 | |
| 1 | 1 | 0 | 1 | 0 | 1 | 50767.4000 | 69 | 200 | |
| 1 | 1 | 1 | 2 | 0 | 2 | 13291.1955 | 0 | 1 | f |
| 2 | 1 | 1 | 2 | 0 | 2 | 52189.8000 | 33 | 200 | |
| 3 | 1 | 2 | 3 | 0 | 3 | 54377.6200 | 86 | 200 | |
| 4 | 1 | 3 | 4 | 0 | 4 | 57394.6000 | 76 | 200 | |
| 6 | 1 | 6 | 5 | 0 | 5 | 144375.4200 | -254 | 200 | |
| 5 | 1 | 4 | 5 | 0 | 5 | 61323.0000 | -429 | 200 | |
| 6 | 1 | 5 | 6 | 0 | 6 | 66262.2200 | 34 | 200 | |
| 7 | 1 | 6 | 7 | 0 | 7 | 72318.1200 | 94 | 200 | |
| 8 | 1 | 7 | 8 | 0 | 8 | 79599.0600 | 270 | 200 | |
| 9 | 1 | 8 | 9 | 0 | 9 | 88201.6600 | -76 | 200 | |
| 13 | 1 | 12 | 13 | 0 | 13 | 136749.3100 | -81 | 200 | |
| 37 | 1 | 36 | 37 | 0 | 37 | 571832.7270 | -158 | 300 | e |
| 4 | 0 | 4 | 3 | 1 | 3 | 25913.0500 | -72 | 200 | |
| 4 | 2 | 2 | 4 | 1 | 3 | 143714.9200 | 207 | 200 | |
| 5 | 0 | 5 | 4 | 1 | 4 | 46232.4000 | 2 | 200 | |
| 6 | 0 | 6 | 5 | 1 | 5 | 66887.5100 | 110 | 200 | |
| 4 | 2 | 2 | 5 | 1 | 5 | 70966.6400 | 123 | 200 | |
| 4 | 2 | 3 | 5 | 1 | 4 | 49650.0000 | 35 | 200 | |
| 5 | 2 | 3 | 5 | 1 | 4 | 140880.1900 | 218 | 200 | |
| 5 | 2 | 3 | 6 | 1 | 6 | 57827.7000 | -27 | 200 | |
| 6 | 2 | 4 | 6 | 1 | 5 | 137821.4700 | 111 | 200 | |
| 7 | 0 | 7 | 6 | 1 | 6 | 87752.9200 | 246 | 200 | |
| 5 | 2 | 4 | 6 | 1 | 5 | 27599.8000 | -10 | 200 | |
| 7 | 2 | 5 | 7 | 1 | 6 | 134717.7300 | -192 | 200 | |
| 6 | 2 | 4 | 7 | 1 | 7 | 45881.4000 | -99 | 200 | |
| 7 | 2 | 5 | 8 | 1 | 8 | 35297.0000 | 42 | 200 | |
| 8 | 2 | 6 | 8 | 1 | 7 | 131766.9100 | -77 | 200 | |
| 9 | 2 | 7 | 10 | 1 | 10 | 18925.2000 | -109 | 200 | |
| 10 | 2 | 8 | 11 | 1 | 11 | 13477.7500 | -10 | 200 | |
| 11 | 2 | 9 | 12 | 1 | 12 | 10047.0000 | 10 | 200 | |
| 12 | 2 | 10 | 13 | 1 | 13 | 8735.2500 | -103 | 200 | |
| 13 | 2 | 11 | 14 | 1 | 14 | 9605.8000 | -30 | 200 | |
| 15 | 2 | 13 | 15 | 1 | 14 | 131783.6400 | 260 | 200 | |
| 14 | 2 | 12 | 15 | 1 | 15 | 12681.6500 | 24 | 200 | |
| 15 | 2 | 13 | 16 | 1 | 16 | 17949.1000 | -45 | 200 | |
| 16 | 2 | 14 | 16 | 1 | 15 | 136657.5500 | 307 | 200 | |
| 17 | 2 | 15 | 17 | 1 | 16 | 143096.2900 | 78 | 200 | |
| 16 | 2 | 14 | 17 | 1 | 17 | 25362.7000 | -15 | 200 | |
| 17 | 2 | 15 | 18 | 1 | 18 | 34849.6000 | 39 | 200 | |
| 19 | 2 | 17 | 19 | 1 | 18 | 160926.6700 | 45 | 200 | |
| 18 | 2 | 16 | 19 | 1 | 19 | 46314.0000 | -41 | 200 | |
| 34 | 0 | 34 | 33 | 1 | 33 | 574425.0980 | -154 | 300 | e |
| 38 | 2 | 37 | 37 | 1 | 36 | 658754.6780 | -100 | 100 | e |
| 60 | 2 | 59 | 59 | 1 | 58 | 1022314.9200 | -66 | 200 | e |
| 8 | 1 | 7 | 7 | 2 | 6 | 18261.7000 | -40 | 200 | |
| 9 | 1 | 8 | 8 | 2 | 7 | 41999.0000 | -135 | 200 | |
| 10 | 1 | 9 | 9 | 2 | 8 | 66210.2600 | 39 | 200 | |
| 11 | 1 | 10 | 10 | 2 | 9 | 90833.5500 | -102 | 200 | |
| 9 | 3 | 7 | 10 | 2 | 8 | 59454.6700 | 21 | 200 | |
| 10 | 3 | 8 | 11 | 2 | 9 | 37345.2000 | -264 | 200 | |
| 10 | 3 | 7 | 11 | 2 | 10 | 57098.7000 | -164 | 200 | |
| 11 | 3 | 8 | 12 | 2 | 11 | 41461.4000 | 58 | 200 | |
| 11 | 3 | 9 | 12 | 2 | 10 | 14330.0500 | -107 | 200 | |
| 13 | 1 | 12 | 12 | 2 | 11 | 141009.7900 | -9 | 200 | |
| 12 | 3 | 9 | 13 | 2 | 12 | 26567.2000 | -135 | 200 | |
| 13 | 3 | 10 | 14 | 2 | 13 | 12568.0000 | -76 | 200 | |
| 16 | 3 | 13 | 15 | 2 | 14 | 566549.9030 | 51 | 100 | e |
| 16 | 3 | 13 | 16 | 2 | 14 | 212789.9500 | 35 | 200 | |
| 26 | 3 | 24 | 25 | 2 | 23 | 573923.2960 | 146 | 300 | e |
| 28 | 3 | 26 | 27 | 2 | 25 | 586826.1430 | 106 | 150 | e |
| 29 | 3 | 27 | 28 | 2 | 26 | 593928.4380 | 104 | 120 | e |
| 28 | 3 | 25 | 29 | 2 | 28 | 15940.3000 | -33 | 200 | |
| 31 | 3 | 29 | 30 | 2 | 28 | 609989.3710 | 70 | 100 | e |
| 29 | 3 | 26 | 30 | 2 | 29 | 33156.1000 | 52 | 200 | |
| 32 | 3 | 30 | 31 | 2 | 29 | 619100.4240 | 60 | 100 | e |
| 30 | 3 | 27 | 31 | 2 | 30 | 52061.6000 | 148 | 200 | |
| 33 | 1 | 32 | 32 | 2 | 31 | 571870.1750 | -86 | 300 | e |
| 39 | 5 | 34 | 39 | 2 | 37 | 1039698.4270 | 100 | 100 | e |
| 44 | 3 | 42 | 44 | 2 | 43 | 627800.4340 | 34 | 300 | e |
| 60 | 1 | 59 | 59 | 2 | 58 | 1022310.1860 | -40 | 250 | e |
| 12 | 4 | 8 | 11 | 3 | 9 | 566790.7410 | 26 | 80 | e |
| 12 | 4 | 9 | 11 | 3 | 8 | 565621.2110 | 19 | 100 | e |
| 13 | 2 | 11 | 12 | 3 | 10 | 9610.0000 | -47 | 200 | |
| 13 | 4 | 10 | 12 | 3 | 9 | 582955.1970 | 37 | 80 | e |
| 13 | 4 | 9 | 12 | 3 | 10 | 584902.2120 | 26 | 60 | e |
| 14 | 2 | 12 | 13 | 3 | 11 | 34462.2000 | -171 | 200 | |
| 13 | 4 | 10 | 14 | 3 | 11 | 91008.5200 | -107 | 200 | |
| 16 | 2 | 15 | 15 | 3 | 12 | 12064.3000 | -109 | 200 | |

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| 14 | 4 | 11 | 15 | 3 | 12 | 70670.7500 | 48 | 200 | |
| 15 | 4 | 12 | 16 | 3 | 13 | 49699.0000 | -123 | 200 | |
| 15 | 4 | 11 | 16 | 3 | 14 | 59503.5000 | -108 | 200 | |
| 17 | 2 | 16 | 16 | 3 | 13 | 22326.7000 | -79 | 200 | |
| 18 | 2 | 17 | 17 | 3 | 14 | 30962.7000 | -192 | 200 | |
| 16 | 4 | 12 | 17 | 3 | 15 | 41768.9000 | -73 | 200 | |
| 16 | 4 | 13 | 17 | 3 | 14 | 27983.7000 | -47 | 200 | |
| 18 | 2 | 16 | 17 | 3 | 15 | 141890.3100 | 223 | 200 | |
| 17 | 4 | 13 | 18 | 3 | 16 | 24344.3000 | -106 | 200 | |
| 19 | 2 | 18 | 18 | 3 | 15 | 37783.9000 | -20 | 200 | |
| 20 | 2 | 19 | 19 | 3 | 16 | 42615.2000 | -202 | 200 | |
| 21 | 2 | 20 | 20 | 3 | 17 | 45307.3000 | 173 | 200 | |
| 22 | 2 | 21 | 21 | 3 | 18 | 45742.0000 | 164 | 200 | |
| 23 | 2 | 22 | 22 | 3 | 19 | 43841.4000 | 16 | 200 | |
| 24 | 2 | 23 | 23 | 3 | 20 | 39569.5000 | -32 | 200 | |
| 25 | 2 | 24 | 24 | 3 | 21 | 32931.5200 | 107 | 200 | |
| 26 | 2 | 25 | 25 | 3 | 22 | 23970.3000 | -86 | 200 | |
| 32 | 4 | 28 | 31 | 3 | 29 | 1059904.2910 | -113 | 150 | e |
| 40 | 4 | 36 | 41 | 3 | 39 | 23320.2500 | -102 | 200 | |
| 6 | 5 | 1 | 5 | 4 | 2 | 558166.1240 | -70 | 120 | e |
| 7 | 5 | 2 | 6 | 4 | 3 | 576240.6300 | -145 | 190 | e |
| 8 | 5 | 3 | 7 | 4 | 4 | 594309.1600 | -394 | 690 | e |
| 9 | 5 | 4 | 8 | 4 | 5 | 612368.6990 | -58 | 100 | e |
| 9 | 5 | 5 | 8 | 4 | 4 | 612366.6380 | -53 | 80 | e |
| 10 | 5 | 6 | 9 | 4 | 5 | 630408.7160 | -31 | 100 | e |
| 10 | 5 | 5 | 9 | 4 | 6 | 630414.1100 | -17 | 100 | e |
| 19 | 3 | 16 | 18 | 4 | 15 | 18095.3000 | -122 | 200 | |
| 20 | 3 | 18 | 19 | 4 | 15 | 9167.5000 | -6 | 200 | |
| 20 | 3 | 17 | 19 | 4 | 16 | 42631.4000 | -96 | 200 | |
| 21 | 3 | 19 | 20 | 4 | 16 | 25012.4000 | 47 | 200 | |
| 21 | 3 | 18 | 20 | 4 | 17 | 68240.3200 | -97 | 200 | |
| 22 | 3 | 19 | 21 | 4 | 18 | 94940.1800 | -321 | 200 | |
| 22 | 3 | 20 | 21 | 4 | 17 | 40061.4000 | 74 | 200 | |
| 21 | 5 | 16 | 22 | 4 | 19 | 45736.6000 | -94 | 200 | |
| 23 | 3 | 21 | 22 | 4 | 18 | 54153.1000 | -99 | 200 | |
| 21 | 5 | 17 | 22 | 4 | 18 | 39724.4000 | -64 | 200 | |
| 22 | 5 | 17 | 23 | 4 | 20 | 27018.7000 | -40 | 200 | |
| 23 | 5 | 18 | 24 | 4 | 21 | 8412.2000 | -113 | 200 | |
| 32 | 5 | 27 | 31 | 4 | 28 | 1040831.0110 | -23 | 100 | e |
| 37 | 3 | 35 | 36 | 4 | 32 | 56467.5000 | -69 | 200 | |
| 38 | 3 | 36 | 37 | 4 | 33 | 39337.8000 | -155 | 200 | |
| 39 | 3 | 37 | 38 | 4 | 34 | 20205.4000 | -158 | 200 | |
| 51 | 5 | 46 | 52 | 4 | 49 | 16970.2500 | -183 | 200 | |
| 54 | 3 | 51 | 53 | 4 | 50 | 952370.2520 | -32 | 100 | e |
| 52 | 5 | 47 | 53 | 4 | 50 | 45284.1500 | -128 | 200 | |
| 55 | 5 | 51 | 54 | 4 | 50 | 1030990.0550 | 2 | 150 | e |
| 56 | 5 | 52 | 55 | 4 | 51 | 1041089.8350 | -9 | 150 | e |
| 6 | 6 | 0 | 6 | 5 | 1 | 549156.2650 | -105 | 100 | e |
| 7 | 6 | 2 | 7 | 5 | 3 | 549151.0180 | -107 | 100 | e |
| 8 | 6 | 2 | 8 | 5 | 3 | 549137.4140 | -101 | 80 | e |
| 9 | 6 | 4 | 9 | 5 | 5 | 549112.4100 | -125 | 80 | e |
| 10 | 6 | 4 | 10 | 5 | 5 | 549072.5730 | -43 | 120 | e |
| 11 | 6 | 6 | 11 | 5 | 7 | 549014.0890 | -252 | 319 | e |
| 12 | 6 | 7 | 12 | 5 | 8 | 548933.0320 | -169 | 200 | e |
| 12 | 6 | 6 | 12 | 5 | 7 | 548932.4080 | -24 | 200 | e |
| 13 | 6 | 8 | 13 | 5 | 9 | 548824.7110 | -106 | 100 | e |
| 13 | 6 | 7 | 13 | 5 | 8 | 548822.9580 | -135 | 100 | e |
| 14 | 6 | 9 | 14 | 5 | 10 | 548684.3100 | -59 | 100 | e |
| 14 | 6 | 8 | 14 | 5 | 9 | 548680.6790 | -67 | 100 | e |
| 16 | 6 | 11 | 16 | 5 | 12 | 548286.5710 | -72 | 120 | e |
| 16 | 6 | 10 | 16 | 5 | 11 | 548272.8570 | -96 | 80 | e |
| 18 | 6 | 12 | 18 | 5 | 13 | 547653.1520 | -49 | 100 | e |
| 18 | 6 | 13 | 18 | 5 | 14 | 547696.9580 | -50 | 80 | e |
| 20 | 6 | 14 | 20 | 5 | 15 | 546749.1330 | -38 | 100 | e |
| 20 | 6 | 15 | 20 | 5 | 16 | 546872.2070 | -25 | 100 | e |
| 22 | 6 | 17 | 21 | 5 | 16 | 944886.8710 | -16 | 100 | e |
| 22 | 6 | 16 | 22 | 5 | 17 | 545463.3590 | -17 | 100 | e |
| 24 | 6 | 18 | 24 | 5 | 19 | 543659.8020 | -1 | 120 | e |
| 25 | 4 | 21 | 24 | 5 | 20 | 25701.3500 | -80 | 200 | |
| 25 | 4 | 22 | 24 | 5 | 19 | 10019.8000 | -85 | 200 | |
| 24 | 6 | 19 | 24 | 5 | 20 | 544379.3470 | -8 | 120 | e |
| 26 | 4 | 22 | 25 | 5 | 21 | 49091.7500 | -81 | 200 | |
| 26 | 4 | 23 | 25 | 5 | 20 | 28202.6000 | 7 | 200 | |
| 26 | 6 | 20 | 26 | 5 | 21 | 541145.2150 | 19 | 120 | e |
| 26 | 6 | 21 | 26 | 5 | 22 | 542688.6420 | 1 | 120 | e |
| 26 | 6 | 21 | 27 | 5 | 22 | 49312.7000 | -44 | 200 | |
| 26 | 6 | 20 | 27 | 5 | 23 | 51717.0000 | -245 | 200 | |
| 28 | 6 | 22 | 28 | 5 | 23 | 537645.9250 | 36 | 150 | e |
| 27 | 6 | 21 | 28 | 5 | 24 | 32436.8000 | -11 | 200 | |
| 27 | 6 | 22 | 28 | 5 | 23 | 29029.4000 | -40 | 200 | |

[e] Cologne measurement.
[f] NIST measurement.
All other frequencies are from the compilation of Lovas.

**TABLE 3**—*Continued*

| Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | | | | | | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 4 | 26 | 28 | 5 | 23 | 80292.7200 | -36 | 200 | | 42 | 7 | 36 | 41 | 8 | 33 | 32735.1000 | 3 | 200 | |
| 28 | 6 | 23 | 29 | 5 | 24 | 8360.6000 | -5 | 200 | | 43 | 7 | 36 | 42 | 8 | 35 | 55238.4000 | 15 | 200 | |
| 28 | 6 | 22 | 29 | 5 | 25 | 13120.1000 | -96 | 200 | | 43 | 7 | 37 | 42 | 8 | 34 | 52749.2000 | 18 | 200 | |
| 30 | 6 | 24 | 30 | 5 | 25 | 532784.9380 | 57 | 100 | e | 42 | 9 | 33 | 43 | 8 | 36 | 53622.5000 | 129 | 200 | |
| 30 | 6 | 25 | 30 | 5 | 26 | 538642.6660 | 24 | 150 | e | 43 | 9 | 34 | 44 | 8 | 37 | 34071.9500 | -136 | 200 | |
| 32 | 6 | 27 | 32 | 5 | 28 | 536552.0100 | 43 | 200 | e | 43 | 9 | 35 | 44 | 8 | 36 | 33830.1000 | -28 | 200 | |
| 35 | 6 | 30 | 35 | 5 | 31 | 533993.6510 | 52 | 100 | e | 44 | 9 | 35 | 45 | 8 | 38 | 14416.9000 | 3 | 200 | |
| 41 | 6 | 36 | 41 | 5 | 37 | 535499.5750 | -21 | 120 | e | 44 | 9 | 36 | 45 | 8 | 37 | 14075.2000 | 152 | 200 | |
| 50 | 4 | 47 | 49 | 5 | 44 | 36251.2000 | -107 | 200 | | 10 | 10 | 0 | 10 | 9 | 1 | 943256.0860 | 174 | 250 | e |
| 51 | 4 | 48 | 50 | 5 | 45 | 10290.5100 | 75 | 200 | | 11 | 10 | 2 | 11 | 9 | 3 | 943284.6350 | 182 | 200 | e |
| 59 | 4 | 55 | 58 | 5 | 54 | 1039962.9990 | 80 | 100 | e | 12 | 10 | 3 | 12 | 9 | 4 | 943312.5450 | 156 | 179 | e |
| 12 | 7 | 6 | 12 | 6 | 7 | 648215.1700 | -84 | 150 | e | 13 | 10 | 4 | 13 | 9 | 5 | 943338.9090 | 21 | 200 | e |
| 13 | 7 | 6 | 13 | 6 | 7 | 648168.9830 | -71 | 80 | e | 14 | 10 | 5 | 14 | 9 | 6 | 943363.2060 | 159 | 120 | e |
| 15 | 7 | 9 | 15 | 6 | 10 | 648020.2740 | -125 | 110 | e | 15 | 10 | 6 | 15 | 9 | 7 | 943384.0560 | 158 | 80 | e |
| 16 | 7 | 9 | 16 | 6 | 10 | 647911.1730 | 49 | 239 | e | 18 | 10 | 9 | 18 | 9 | 10 | 943416.0270 | 159 | 120 | e |
| 17 | 7 | 11 | 17 | 6 | 12 | 647774.1340 | -288 | 479 | e | 21 | 10 | 12 | 21 | 9 | 13 | 943376.6760 | 138 | 120 | e |
| 18 | 7 | 11 | 18 | 6 | 12 | 647604.7240 | -49 | 100 | e | 22 | 10 | 12 | 22 | 9 | 13 | 943341.4720 | 187 | 150 | e |
| 18 | 7 | 12 | 18 | 6 | 13 | 647605.7220 | -17 | 100 | e | 23 | 10 | 13 | 23 | 9 | 14 | 943292.5900 | 112 | 200 | e |
| 19 | 7 | 13 | 19 | 6 | 14 | 647401.2340 | 8 | 100 | e | 24 | 10 | 14 | 24 | 9 | 15 | 943228.1160 | -401 | 400 | e |
| 19 | 7 | 12 | 19 | 6 | 13 | 647399.3330 | -44 | 100 | e | 25 | 10 | 15 | 25 | 9 | 16 | 943147.9400 | 202 | 300 | e |
| 20 | 7 | 14 | 20 | 6 | 15 | 647156.5320 | -42 | 100 | e | 26 | 10 | 17 | 26 | 9 | 18 | 943048.4480 | 55 | 300 | e |
| 20 | 7 | 13 | 20 | 6 | 14 | 647153.1140 | -49 | 120 | e | 27 | 10 | 18 | 27 | 9 | 19 | 942928.7740 | 109 | 300 | e |
| 21 | 7 | 15 | 21 | 6 | 16 | 646867.2230 | -52 | 100 | e | 28 | 10 | 19 | 28 | 9 | 20 | 942786.7570 | 98 | 150 | e |
| 21 | 7 | 14 | 21 | 6 | 15 | 646861.1300 | -45 | 100 | e | 29 | 10 | 20 | 29 | 9 | 21 | 942620.5930 | 191 | 300 | e |
| 22 | 7 | 16 | 21 | 6 | 15 | 1045254.0880 | -29 | 80 | e | 47 | 8 | 39 | 46 | 9 | 38 | 25883.6000 | -101 | 200 | |
| 22 | 7 | 15 | 21 | 6 | 16 | 1045260.4620 | -127 | 80 | e | 47 | 8 | 40 | 46 | 9 | 37 | 25218.9500 | -42 | 200 | |
| 22 | 7 | 16 | 22 | 6 | 17 | 646528.5880 | -41 | 100 | e | 46 | 10 | 36 | 47 | 9 | 39 | 80287.5400 | 1 | 200 | |
| 23 | 7 | 16 | 23 | 6 | 17 | 646117.8090 | -37 | 100 | e | 48 | 8 | 41 | 47 | 9 | 38 | 45202.9000 | 54 | 200 | |
| 23 | 7 | 17 | 23 | 6 | 18 | 646135.7440 | -40 | 100 | e | 48 | 8 | 40 | 47 | 9 | 39 | 46118.0500 | -137 | 200 | |
| 26 | 7 | 19 | 26 | 6 | 20 | 644506.4270 | -32 | 120 | e | 48 | 10 | 38 | 49 | 9 | 41 | 41452.5500 | 73 | 200 | |
| 27 | 7 | 20 | 27 | 6 | 21 | 643805.2160 | -6 | 100 | e | 48 | 10 | 39 | 49 | 9 | 40 | 41368.2000 | -14 | 200 | |
| 27 | 7 | 21 | 27 | 6 | 22 | 643923.1280 | -8 | 100 | e | 49 | 10 | 40 | 50 | 9 | 41 | 21775.2000 | -19 | 200 | |
| 28 | 7 | 21 | 28 | 6 | 22 | 643005.4670 | -17 | 100 | e | 49 | 10 | 39 | 50 | 9 | 42 | 21894.8000 | 39 | 200 | |
| 28 | 7 | 22 | 28 | 6 | 23 | 643185.5470 | 23 | 100 | e | 11 | 11 | 1 | 11 | 10 | 2 | 1040624.6890 | -107 | 100 | e |
| 27 | 7 | 21 | 28 | 6 | 22 | 135306.9600 | 271 | 200 | | 12 | 11 | 2 | 12 | 10 | 3 | 1040662.6290 | -112 | 100 | e |
| 29 | 7 | 23 | 29 | 6 | 24 | 642365.4770 | -10 | 100 | e | 13 | 11 | 3 | 13 | 10 | 4 | 1040700.9280 | -143 | 100 | e |
| 29 | 7 | 22 | 29 | 6 | 23 | 642095.0400 | -51 | 100 | e | 14 | 11 | 4 | 14 | 10 | 5 | 1040738.9050 | -218 | 100 | e |
| 30 | 5 | 25 | 29 | 6 | 24 | 12763.2000 | 20 | 200 | | 15 | 11 | 5 | 15 | 10 | 6 | 1040776.0710 | -112 | 70 | e |
| 30 | 7 | 24 | 30 | 6 | 25 | 641459.7120 | -11 | 100 | e | 16 | 11 | 6 | 16 | 10 | 7 | 1040811.2580 | -228 | 100 | e |
| 31 | 5 | 26 | 30 | 6 | 25 | 34421.9000 | -66 | 200 | | 17 | 11 | 6 | 17 | 10 | 7 | 1040844.1140 | -102 | 60 | e |
| 31 | 5 | 27 | 30 | 6 | 24 | 25503.9500 | -58 | 200 | | 20 | 11 | 10 | 20 | 10 | 11 | 1040917.9240 | -146 | 100 | e |
| 30 | 7 | 23 | 30 | 6 | 24 | 641059.9680 | 92 | 120 | e | 21 | 11 | 11 | 21 | 10 | 12 | 1040931.8770 | 519 | 100 | e |
| 32 | 5 | 28 | 31 | 6 | 25 | 44731.5000 | -257 | 200 | | 22 | 11 | 11 | 22 | 10 | 12 | 1040937.3440 | 100 | 100 | e |
| 31 | 7 | 25 | 31 | 6 | 26 | 640465.8970 | 0 | 100 | e | 23 | 11 | 13 | 23 | 10 | 14 | 1040934.6900 | 79 | 100 | e |
| 30 | 7 | 23 | 31 | 6 | 26 | 77973.3800 | 42 | 200 | | 24 | 11 | 13 | 24 | 10 | 14 | 1040922.2530 | -39 | 100 | e |
| 31 | 7 | 24 | 31 | 6 | 25 | 639883.2230 | 11 | 100 | e | 25 | 11 | 14 | 25 | 10 | 15 | 1040898.6790 | -389 | 609 | e |
| 32 | 5 | 27 | 31 | 6 | 26 | 56706.1000 | -214 | 200 | | 26 | 11 | 16 | 26 | 10 | 17 | 1040863.6140 | -53 | 70 | e |
| 32 | 7 | 25 | 32 | 6 | 26 | 638545.5040 | 0 | 100 | e | 25 | 11 | 15 | 26 | 10 | 16 | 570320.5910 | -69 | 300 | e |
| 32 | 7 | 26 | 32 | 6 | 27 | 639382.9400 | -9 | 100 | e | 27 | 11 | 17 | 27 | 10 | 18 | 1040814.8020 | 33 | 100 | e |
| 31 | 7 | 24 | 32 | 6 | 27 | 58599.2000 | -287 | 200 | | 28 | 11 | 18 | 28 | 10 | 19 | 1040750.9270 | -67 | 60 | e |
| 32 | 7 | 26 | 33 | 6 | 27 | 37826.5000 | -324 | 200 | | 29 | 11 | 18 | 29 | 10 | 19 | 1040670.8530 | -64 | 60 | e |
| 32 | 7 | 25 | 33 | 6 | 28 | 39127.4000 | -142 | 200 | | 30 | 11 | 20 | 30 | 10 | 21 | 1040572.9980 | -55 | 100 | e |
| 33 | 7 | 27 | 33 | 6 | 28 | 638211.4310 | -10 | 100 | e | 31 | 11 | 21 | 31 | 10 | 22 | 1040456.2370 | 372 | 100 | e |
| 33 | 7 | 26 | 33 | 6 | 27 | 637023.6100 | 2 | 100 | e | 32 | 11 | 22 | 32 | 10 | 23 | 1040317.7100 | -46 | 100 | e |
| 33 | 7 | 27 | 34 | 6 | 28 | 17727.7500 | -3 | 200 | | 33 | 11 | 22 | 33 | 10 | 23 | 1040157.0400 | -35 | 100 | e |
| 33 | 7 | 26 | 34 | 6 | 29 | 19561.9000 | -181 | 200 | | 34 | 11 | 24 | 34 | 10 | 25 | 1039972.1060 | -8 | 100 | e |
| 34 | 7 | 28 | 34 | 6 | 29 | 636953.9490 | 8 | 150 | e | 35 | 11 | 25 | 35 | 10 | 26 | 1039761.0330 | -66 | 100 | e |
| 34 | 7 | 27 | 34 | 6 | 28 | 635290.1580 | -20 | 80 | e | 36 | 11 | 26 | 36 | 10 | 27 | 1039522.1630 | -33 | 70 | e |
| 35 | 7 | 28 | 35 | 6 | 29 | 633312.9930 | 6 | 100 | e | 37 | 11 | 27 | 37 | 10 | 28 | 1039253.4810 | -26 | 70 | e |
| 35 | 7 | 29 | 35 | 6 | 30 | 635615.4010 | -33 | 120 | e | 38 | 11 | 27 | 38 | 10 | 28 | 1038953.2630 | 220 | 150 | e |
| 62 | 5 | 58 | 61 | 6 | 55 | 18589.5500 | -65 | 200 | | 39 | 11 | 28 | 39 | 10 | 29 | 1038619.1270 | 324 | 200 | e |
| 11 | 8 | 4 | 10 | 7 | 3 | 945944.1050 | 31 | 100 | e | 40 | 11 | 30 | 40 | 10 | 31 | 1038248.7580 | 16 | 120 | e |
| 15 | 8 | 8 | 14 | 7 | 7 | 1018318.9930 | 38 | 150 | e | 41 | 11 | 30 | 41 | 10 | 31 | 1037840.4880 | 46 | 150 | e |
| 16 | 8 | 9 | 15 | 7 | 8 | 1036398.7660 | 29 | 60 | e | 42 | 11 | 32 | 42 | 10 | 33 | 1037391.9490 | -120 | 200 | e |
| 17 | 8 | 10 | 16 | 7 | 9 | 1054469.4880 | 27 | 60 | e | 43 | 11 | 33 | 43 | 10 | 34 | 1036900.7340 | -178 | 319 | e |
| 36 | 6 | 30 | 35 | 7 | 29 | 23337.2000 | -118 | 200 | | 47 | 11 | 37 | 47 | 10 | 38 | 1034460.0560 | 126 | 150 | e |
| 36 | 6 | 31 | 35 | 7 | 28 | 19813.3000 | -97 | 200 | | 47 | 11 | 36 | 47 | 10 | 37 | 1034457.9860 | -124 | 150 | e |
| 37 | 6 | 31 | 36 | 7 | 30 | 44398.8000 | -204 | 200 | | 48 | 11 | 37 | 48 | 10 | 38 | 1033714.4870 | -133 | 150 | e |
| 37 | 6 | 32 | 36 | 7 | 29 | 39594.4000 | 99 | 200 | | 48 | 11 | 38 | 48 | 10 | 39 | 1033717.4530 | 96 | 150 | e |
| 38 | 6 | 33 | 37 | 7 | 30 | 59408.7000 | -93 | 200 | | 50 | 11 | 40 | 50 | 10 | 41 | 1032053.4910 | -40 | 150 | e |
| 37 | 8 | 30 | 38 | 7 | 31 | 45832.1000 | -55 | 200 | | 50 | 11 | 39 | 50 | 10 | 40 | 1032047.4330 | -74 | 150 | e |
| 37 | 8 | 29 | 38 | 7 | 32 | 46309.0000 | -142 | 200 | | 52 | 9 | 44 | 51 | 10 | 41 | 17520.1500 | 12 | 200 | |
| 38 | 8 | 30 | 39 | 7 | 33 | 26706.9000 | -31 | 200 | | 52 | 9 | 43 | 51 | 10 | 42 | 17755.1000 | 36 | 200 | |
| 38 | 8 | 31 | 39 | 7 | 32 | 26029.9000 | 0 | 200 | | 53 | 9 | 45 | 52 | 10 | 42 | 37384.4000 | 81 | 200 | |
| 9 | 9 | 1 | 8 | 8 | 0 | 1008087.4440 | 284 | 200 | e | 53 | 9 | 44 | 52 | 10 | 43 | 37709.9500 | 35 | 200 | |
| 10 | 9 | 1 | 9 | 8 | 2 | 1026196.1080 | 138 | 50 | e | 54 | 9 | 45 | 53 | 10 | 44 | 57805.0000 | 2 | 200 | |
| 11 | 9 | 3 | 10 | 8 | 2 | 1044306.2650 | 110 | 100 | e | 54 | 9 | 46 | 53 | 10 | 43 | 57357.2000 | 171 | 200 | |
| 12 | 9 | 4 | 11 | 8 | 3 | 1062417.1030 | 150 | 50 | e | 53 | 11 | 42 | 54 | 10 | 45 | 48765.0000 | 184 | 200 | |
| 41 | 7 | 34 | 40 | 8 | 33 | 14140.5000 | -92 | 200 | | 53 | 11 | 43 | 54 | 10 | 44 | 48736.2000 | 92 | 200 | |
| 41 | 7 | 35 | 40 | 8 | 32 | 12817.4000 | -40 | 200 | | 55 | 11 | 44 | 56 | 10 | 47 | 9790.3500 | 22 | 200 | |

**TABLE 3**—*Continued*

| Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. | Transition | Frequency (MHZ) | Obs. - Calc. (kHz) | Exp. Unc. (kHz) | Ref. |
|---|---|---|---|---|---|---|---|---|---|
| 55 11 45 56 10 46 | 9732.6000 | -26 | 200 | | 64 11 54 63 12 51 | 41425.2000 | -1 | 200 | |
| 57 10 48 56 11 45 | 9831.0800 | 464 | 200 | | 64 13 52 65 12 53 | 43860.6000 | 35 | 200 | |
| 57 10 47 56 11 46 | 9912.0000 | 461 | 200 | | 64 13 51 65 12 54 | 43865.0000 | -61 | 200 | |
| 58 10 49 57 11 46 | 29545.5000 | -46 | 200 | | 65 13 53 66 12 54 | 24595.6000 | -8 | 200 | |
| 58 10 48 57 11 47 | 29658.3000 | 46 | 200 | | 65 13 52 66 12 55 | 24601.9500 | -40 | 200 | |
| 59 12 48 60 11 49 | 36637.4000 | 56 | 200 | | 68 12 57 67 13 54 | 14129.1500 | -93 | 200 | |
| 59 12 47 60 11 50 | 36651.1000 | 77 | 200 | | 69 12 58 68 13 55 | 33602.8000 | -118 | 200 | |
| 60 12 49 61 11 50 | 17233.5000 | 154 | 200 | | 69 12 57 68 13 56 | 33620.5000 | -9 | 200 | |
| 60 12 48 61 11 51 | 17252.9000 | 179 | 200 | | 70 14 56 71 13 59 | 31825.6000 | -99 | 200 | |
| 63 11 52 62 12 51 | 21820.0000 | -224 | 200 | | 70 14 57 71 13 58 | 31823.5500 | -84 | 200 | |
| 64 11 53 63 12 52 | 41478.1000 | -49 | 200 | | 19 15 5 20 14 6 | 1062390.2570 | 259 | 250 | e |

For the $^{34}SO_2$ and the $^{32}S^{18}O^{16}O$ isotopic species, 298 and 342 transitions were fit. In the fitting, each datum was assigned a weight equal to the square of the reciprocal of its estimated experimental uncertainty. The weights cover a large dynamic range, starting with 0.028 for the far infrared data reaching $10^6$ for the most precise FTMW measurements.

In the data analysis, a standard Watson Hamiltonian (*12*) was used in the $I^r$ representation. Since levels with high values of the rotational quantum numbers were included in the fittings, it was necessary to include higher-order diagonal terms through $P^{10}$. These terms were added one-by-one until the data fit to within the estimated experimental uncertainty. These very high-order terms should be regarded as empirical fitting parameters with very little physical significance. Since the data is more limited for the $^{34}SO_2$ and $^{32}S^{18}O^{16}O$ isotopic species, a number of the higher-order terms could not be obtained in the fittings, and these were fixed at the values derived for the most abundant isotopics species. The microwave data used in these fittings are given in Tables 1–3, and the spectroscopic constants obtained are

**TABLE 4**
**Ground State Rotational Constants of Several Isotopic Species of Sulfur Dioxide in MHz**

| | $^{32}S^{16}O_2$ | $^{34}S^{16}O_2$ | $^{32}S^{18}O^{16}O$ |
|---|---|---|---|
| A | 60778.5497700(4400) | 58991.1829500(5101) | 59101.1689600(26823) |
| B | 10318.0734800(764) | 10318.5099300(899) | 9724.6428400(5571) |
| C | 8799.7033990(699) | 8761.3024810(972) | 8331.5601810(5109) |
| $\Delta_J \times 10^{-3}$ | 6.611475(128) | 6.568494(162) | 5.903075(378) |
| $\Delta_{JK} \times 10^{-1}$ | -1.1696161(206) | -1.1166602(267) | -1.0835815(429) |
| $\Delta_K$ | 2.59034044(745) | 2.44020246(1024) | 2.44293678(6249) |
| $\delta_J \times 10^{-3}$ | 1.7010282(106) | 1.7222182(261) | 1.4878101(941) |
| $\delta_K \times 10^{-2}$ | 2.536981(118) | 2.461910(153) | 2.312804(1606) |
| $H_J \times 10^{-8}$ | 1.10634(378) | 1.10715(375) | 0.90292(626) |
| $H_{JK} \times 10^{-8}$ | 2.358(170) | 1.252(199) | 0.724(1863) |
| $H_{KJ} \times 10^{-5}$ | -1.945017(713) | -1.809302(957) | -1.680719(6988) |
| $H_K \times 10^{-4}$ | 3.710988(566) | 3.393985(709) | 3.273802(5153) |
| $h_J \times 10^{-9}$ | 5.40214(644) | 5.41571(1271) | 4.48579(1559) |
| $h_{JK} \times 10^{-9}$ | -1.143(969) | -1.143[a] | -1.143[a] |
| $h_K \times 10^{-5}$ | 1.66358(610) | 1.53908(654) | 1.32775(8790) |
| $L_J \times 10^{-15}$ | -9.74(277) | -9.74[a] | -9.74[a] |
| $L_{JJK} \times 10^{-13}$ | -2.062(905) | -2.062[a] | -2.062[a] |
| $L_{KJ} \times 10^{-11}$ | 2.042(193) | 2.181(227) | -4.227(1233) |
| $L_{KKJ} \times 10^{-9}$ | 4.4668(282) | 4.3159(465) | 1.74341930) |
| $L_K \times 10^{-8}$ | -7.9119(209) | -7.1818(272) | -1.6366(1235) |
| $P_{KKKJJ} \times 10^{-14}$ | 3.991(356) | 3.991[a] | 3.991[a] |
| $P_{KKKJ} \times 10^{-12}$ | -1.5212(561) | -2.0704(628) | -1.5212[a] |
| $P_K \times 10^{-11}$ | 1.8650(314) | 1.9609(368) | 1.8650[a] |

[a] Fixed at value of $^{32}S^{16}O_2$ isotopic species.

presented in Table 4. The uncertainties in the constants are one standard deviation.

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