Microwave Spectra of Molecules of Astrophysical Interest

XI. Silicon Sulfide

Eberhard Tiemann

Institut für Molekülphysik, Freie Universität Berlin, Boltzmannstraße 20, 1000 Berlin 33, Germany

The available data on the microwave spectrum of silicon sulfide are critically reviewed for information applicable to radio astronomy. Molecular data such as rotational constants, electric dipole moment and hyperfine coupling constant are tabulated. Observed rotational transitions are presented for all measured isotopic forms of SiS. These data have been analyzed in order to predict rotational transition of the ground vibrational state up to 300 GHz. From the given rotational constants transition frequencies in excited vibrational states can be calculated with little loss in accuracy.

Error limits have been taken from the original literature for each measured frequency. The predicted transition frequencies are given with uncertainties which represent the 90 percent confidence limit.

Key Words: Interstellar molecules; microwave spectra; radio astronomy; rotational transitions; silicon sulfide; spectra.

Contents

1. Introduction

The present tables are part of a series of critical reviews on rotational spectra of molecules already identified in the interstellar medium (see list in ref. [1][1]). All of the available data have been gathered for silicon sulfide and subjected to reanalysis in order to provide a consistent set of molecular constants and a check on the reliability of the measured transitions, and to allow a prediction of unobserved transition frequencies with known uncertainty limits. This review covers all information available as of January 1, 1976.

A full description of the theory of rotational spectra is given in a number of texts, but the discussions by Townes and Schawlow [2] and Gordy and Cook [3] are particularly useful and the notation used here is generally consistent with these texts. The present analysis utilize the Dunham [4] nomenclature for describing the molecular parameters and energy level expressions.

The general equation for calculating the transition frequencies is:

$$\nu_{v,J\to J-1}=2J[Y_{01}+Y_{11}(v+1/2)+Y_{21}(v+1/2)^2]+4J^3[Y_{02}]. \qquad (1)$$

Here J presents the rotational quantum number of the upper state involved in the transition, v is the vibrational quantum number and ν is the transition frequency.

Equation (1) only includes the known Dunham coefficients Y_{lk} for SiS. Higher order terms are not necessary for the accuracy given in the spectral tables.

---

[1] Numbers in brackets indicate references in section 1.2.

The Y_{lk} are proportional to the reduced mass μ_r of the molecules as follows:

$$Y_{01} \alpha \mu_r^{-1} \tag{2a}$$

$$Y_{11} \alpha \mu_r^{-3/2} \tag{2b}$$

$$Y_{21} \alpha \mu_r^{-2} \tag{2c}$$

$$Y_{02} \alpha \mu_r^{-2} \tag{2d}$$

These equations are true if the Born-Oppenheimer approximation holds. At present, differences from the relations (2) are observed only for Y_{01}, so the constants Y_{01} are given independently for each isotopic form of SiS without any use of mass relations in the analysis procedure. For $^{28}Si^{33}S$ quadrupole hyperfine structure is reported. The calculation is based on the usual expression:

$$\Delta\nu = -eqQ \cdot f(I, J, F), \tag{3}$$

where $f(I, J, F)$ is the Casimir function. The values of the Casimir function as well as the calculated relative intensities for the hyperfine components of each rotational transition can be found in Appendix I of ref. [2].

The present tables do not include line strengths other than the relative intensities of the components of nuclear electric quadrupole hyperfine structure. The line strength S, is a simple function of the quantum numbers as follows:

$$S(J', J'') = J', \tag{4}$$

and the Einstein coefficient for spontaneous emission is given by:

$$A(J', J'') = \frac{1.1639 \times 10^{-20} \nu^3 \mu^2}{2J'+1} \cdot S(J', J''), \tag{5}$$

where μ is the dipole moment in Debye, ν is the transition frequency in MHz, and A the transition rate per second.

1.1. List of Symbols and Conversion Factors

Y_{lk}	Dunham coefficients in the power series expansion of J and v for the rotational and vibrational energy expression (MHz and kHz). See text.
eqQ	Nuclear electric quadrupole coupling constant (MHz).
J	Rotational angular momentum quantum number.
F	Total angular momentum quantum number.
I	Nuclear spin angular momentum quantum number. (for ^{33}S : $I = 3/2$).
v	Vibrational quantum number.
μ_v	Dipole moment of the molecule in the v th vibrational state (Debye).
μ_r	Reduced mass (amu).
$\omega_e \approx Y_{10}$	Harmonic vibrational frequency of the molecule.
(. . .)	Parentheses in the numerical listings contain measured or estimated uncertainties. These should be interpreted as: 2.57(0.39) kHz = 2.57(39) kHz = 2.57 ± 0.39 kHz.
′ and ″	Prime and double prime superscripts to the quantum number indicators which refer to the upper and lower energy state, respectively.

Conversion factor: $1\ \text{cm}^{-1} \doteq 29{,}979.2458\ \text{MHz}$
$\doteq 1.986478(11) \times 10^{-23}\ J$

1.2. References

[1] A. Bauder, F. J. Lovas and D. R. Johnson, J. Phys. Chem. Ref. Data 5, 53 (1976).

[2] C. H. Townes and A. L. Schawlow, Microwave Spectroscopy, McGraw-Hill, New York, 1955.

[3] W. Gordy and R. L. Cook, Microwave Molecular Spectra, John Wiley & Sons, New York, 1970.

[4] J. L. Dunham, Phys. Rev. 41, 721 (1932).

2. Silicon Sulfide

The measured rotational spectra of all isotopic forms of silicon sulfide were fitted in a weighted least squares procedure to the rotational constants Y_{lk} which are given in table 1. The parameters Y_{11}, Y_{21}, and Y_{02} for the various isotopic forms were coupled by the mass relations (2b)–(2d). Only the Y_{01}'s were varied independently in the fit.

Uncertainties shown in table 1 are two standard deviations generated by the fit. This gives approximately the 90 percent confidence limit.

Some other molecular parameters are reported in table 1 which may be important for the interpretation of the interstellar radio spectra.

2.1. Organization of the Spectral Tables

Tables 2 through 6 contain the rotational spectra of the various isotopic forms of silicon sulfide, which are observed with microwave spectroscopy in the laboratory. The first two columns show the rotational quantum numbers, J, which are involved in the transition, and the third column contains the vibrational state quantum number v. These are followed by the observed transition frequency and the calculated frequency from the molecular parameter given in table 1. The calculation of the uncertainty includes correlation of the fitted parameters and the tabulated value represents the 90 percent confidence limit. The prediction of unobserved transition frequencies was restricted to the maximum calculated frequency of approximately 300 GHz which is more than sufficient to cover the frequency range of existing radio telescopes.

The sixth column of these tables contains the upper state energy in equivalent cm^{-1} units (E/hc). The last column lists the references for the laboratory measurements. For the convenience of the user, the transition frequencies given in tables 2–6 are listed in order of increasing frequency in table 7.

For the isotopic form $^{28}Si^{33}S$ the hypothetical center frequencies are shown without hyperfine components.

2.2. Silicon Sulfide Spectral Tables

Table 1. Molecular Constants of Silicon Sulfide

	$^{28}Si^{32}S$	$^{29}Si^{32}S$	$^{30}Si^{32}S$	$^{28}Si^{34}S$	$^{28}Si^{33}S$	Ref.
Y_{01} (MHz)	9099.5369(15)	8932.1374(17)	8776.2495(19)	8850.0451(16)	8970.8296(20)	a
Y_{11} (MHz)	- 44.1617(15)	- 42.9486(15)	- 41.8292(15)	- 42.3578(15)	- 43.2280(15)	a
Y_{21} (kHz)	- 2.57 (39)	- 2.48 (39)	- 2.39 (39)	- 2.43 (39)	- 2.50 (39)	a
Y_{02} (kHz)	- 6.016 (70)	- 5.797 (70)	- 5.596 (70)	- 5.692 (70)	- 5.847 (70)	a
eqQ (^{33}S) (MHz)	--	--	--	--	10.90 (20)	[70A]
μ_0(Debye)	1.73 (6)					[69A]
ω_e(cm^{-1})	746.6 (22)[b] 749.6_9 [c]					

[a] Refit of data from reference [69A] and [72A] including effects of the breakdown of the Born Oppenheimer approximation. Uncertainties given are two standard deviations generated by a least squares fit with 25 degrees of freedom.

[b] Calculated with the centrifugal distortion constant Y_{02}, using Kratzer's relation $Y_{02}=-\frac{4B_e^3}{\omega_e^2}$, $B_e \approx Y_{01}$.

[c] From an analysis of the optical spectrum of SiS: A. Lagerquist, G. Nilheden and R.F. Barrow Proc. Phys. Soc. A 65, 419 (1952).

Table 2. Microwave Spectrum of $^{28}Si^{32}S$

Transition Upper State J'	 Lower State J"	Vib. State v	Observed Frequency (Est. Unc.) MHz	Calculated Frequency (Est. Unc.)[a] MHz	Energy Levels (cm^{-1}) Upper State	Ref.
1	0	0	18154.881(15)	18154.887(2)	0.61	[69A]
1	0	1	18066.554(15)	18066.553(2)	744.47	[69A]
1	0	2	17978.215(15)	17978.209(2)	1482.91	[69A]
1	0	3	17889.856(20)	17889.855(3)	2215.93	[69A]
1	0	4	17801.494(30)	17801.490(5)	2943.52	[69A]
2	1	0	36309.631(4)	36309.629(3)	1.82	[72A]
2	1	1	36132.962(5)	36132.962(3)	745.69	[72A]
2	1	2	35956.270(5)	35956.274(3)	1484.13	[72A]
2	1	3	35779.561(8)	35779.565(4)	2217.14	[72A]
3	2	0	54464.081(4)	54464.083(4)	3.64	[72A]
3	2	1	54199.084(7)	54199.082(4)	747.51	[72A]
3	2	2	53934.052(9)	53934.050(5)	1485.95	[72A]
3	2	3	53668.993(9)	53668.987(6)	2218.96	[72A]
3	2	4	53403.889(30)	53403.894(15)	2946.55	[72A]
4	3	0		72618.103(10)	6.07	
4	3	1		72264.768(12)	749.94	
5	4	0		90771.546(26)	9.11	
5	4	1		90329.877(27)	752.97	
6	5	0		108924.267(48)	12.75	
6	5	1		108394.265(50)	756.61	
7	6	0		127076.121(82)	17.00	
7	6	1		126457.785(84)	760.86	
8	7	0		145226.965(128)	21.85	
8	7	1		144520.295(130)	765.72	
9	8	0		163376.653(186)	27.32	
9	8	1		162581.650(188)	771.18	
10	9	0		181525.043(260)	33.39	
10	9	1		180641.706(264)	777.25	
11	10	0		199671.988(352)	40.07	
11	10	1		198700.318(355)	783.93	
12	11	0		217817.345(461)	47.35	
12	11	1		216757.341(465)	791.22	
13	12	0		235960.969(591)	55.24	
13	12	1		234812.631(595)	799.11	
14	13	0		254102.716(743)	63.74	
14	13	1		252866.045(747)	807.61	
15	14	0		272242.442(918)	72.85	
15	14	1		270917.437(923)	816.71	
16	15	0		290380.002(1119)	82.56	
16	15	1		288966.663(1124)	826.42	

[a] Uncertainties represent 90% confidence limit.

Table 3. Microwave Spectrum of $^{29}Si^{32}S$

Transition Upper State J'	 Lower State J"	Vib. State v	Observed Frequency (Est. Unc.) MHz	Calculated Frequency (Est. Unc.)[a] MHz	Energy Levels (cm^{-1}) Upper State	Ref.
1	0	0	17821.309(20)	17821.302(3)	0.60	[69A]
1	0	1	17735.403(20)	17735.395(3)	737.61	[69A]
2	1	0	35642.465(8)	35642.464(5)	1.79	[72A]
2	1	1	35470.625(40)	35470.650(5)	738.80	[72A]
3	2	0	53463.348(8)	53463.349(7)	3.58	[72A]
3	2	1	53205.633(30)	53205.627(8)	740.59	[72A]
4	3	0		71283.816(13)	5.96	
5	4	0		89103.726(26)	8.94	
6	5	0		106922.941(48)	12.51	
7	6	0		124741.322(80)	16.68	
8	7	0		142558.728(124)	21.45	
9	8	0		160375.021(181)	26.81	
10	9	0		178190.062(252)	32.77	
11	10	0		196003.712(340)	39.33	
12	11	0		213815.832(445)	46.48	
13	12	0		231626.282(570)	54.23	
14	13	0		249434.923(716)	62.57	
15	14	0		267241.616(885)	71.51	
16	15	0		285046.223(1079)	81.04	

[a] Uncertainties represent 90% confidence limit.

Table 4. Microwave Spectrum of $^{30}Si^{32}S$

Transition Upper State J'	 Lower State J"	Vib. State v	Observed Frequency (Est. Unc.) MHz	Calculated Frequency (Est. Unc.)[a] MHz	Energy Levels (cm^{-1}) Upper State	Ref.
1	0	0	17510.650(15)	17510.646(3)	0.59	[69A]
1	0	1	17426.971(20)	17426.978(3)	731.16	[69A]
2	1	0	35021.153(9)	35021.158(6)	1.76	[72A]
2	1	1	34853.818(40)	34853.822(6)	732.34	[72A]
3	2	0	52531.408(12)	52531.401(9)	3.51	[72A]
3	2	1	52280.392(40)	52280.398(10)	734.09	[72A]
4	3	0		70041.242(15)	5.85	
5	4	0		87550.545(28)	8.78	
6	5	0		105059.176(49)	12.30	
7	6	0		122567.002(80)	16.39	
8	7	0		140073.887(122)	21.08	
9	8	0		157579.698(177)	26.35	
10	9	0		175084.300(246)	32.20	
11	10	0		192587.559(331)	38.64	
12	11	0		210089.341(433)	45.67	
13	12	0		227589.511(554)	53.28	
14	13	0		245087.934(695)	61.48	
15	14	0		262584.478(858)	70.26	
16	15	0		280079.006(1045)	79.63	
17	16	0		297571.386(1257)	89.58	

[a] Uncertainties represent 90% confidence limit.

Table 5. Microwave Spectrum of $^{28}Si^{34}S$

Transition Upper State J'	Transition Lower State J"	Vib. State v	Observed Frequency (Est. Unc.) MHz	Calculated Frequency (Est. Unc.)[a] MHz	Energy Levels (cm^{-1}) Upper State	Ref.
1	0	0	17657.718(15)	17657.708(3)	0.59	[69A]
1	0	1	17573.005(20)	17572.983(3)	734.22	[69A]
2	1	0	35315.283(7)	35315.280(4)	1.77	[72A]
2	1	1	35145.796(40)	35145.829(5)	735.40	[72A]
3	2	0	52972.575(8)	52972.579(6)	3.54	[72A]
3	2	1	52718.402(30)	52718.402(8)	737.18	[72A]
4	3	0		70629.468(13)	5.90	
5	4	0		88285.810(26)	8.86	
6	5	0		105941.470(48)	12.40	
7	6	0		123596.310(79)	16.53	
8	7	0		141250.194(122)	21.25	
9	8	0		158902.985(178)	26.57	
10	9	0		176554.548(248)	32.47	
11	10	0		194204.744(334)	38.97	
12	11	0		211853.438(438)	46.05	
13	12	0		229500.493(561)	53.73	
14	13	0		247145.773(704)	61.99	
15	14	0		264789.140(870)	70.85	
16	15	0		282430.459(1060)	80.30	

[a] Uncertainties represent 90% confidence limit.

Table 6. Microwave Spectrum of $^{28}\mathrm{Si}^{33}\mathrm{S}$

Transition Upper State J' F'-	 Lower State J" F"	Observed Frequency (Est. Unc.) MHz	Calculated Frequency[a] (Est. Unc.) MHz	Relative Intensity	Energy Levels (cm^{-1}) Upper State	Ref.
1	0		17898.407(4)		0.59	
1/2	3/2	17895.673(50)	17895.682(54)	0.17		[70A]
5/2	3/2	17897.874(30)	17897.862(15)	0.50		[70A]
3/2	3/2	17900.584(30)	17900.587(44)	0.33		[70A]
2	1		35796.673(5)		1.78	
1/2	3/2		35791.768(85)	0.02		
3/2	3/2		35794.493(45)	0.11		
5/2	3/2		35796.439(9)	0.21		
7/2	5/2		35796.439(9)	0.40		
1/2	1/2		35796.673(5)	0.08		
3/2	5/2		35797.218(15)	0.01		
5/2	5/2		35799.164(55)	0.09		
3/2	1/2		35799.398(59)	0.08		
3	2		53694.658(8)		3.57	
5/2	5/2		53693.257(36)	0.05		
7/2	5/2		53694.528(10)	0.25		
9/2	7/2		53694.528(10)	0.36		
3/2	1/2		53695.203(18)	0.10		
5/2	3/2		53695.203(18)	0.16		
4	3		71592.223(15)		5.96	
9/2	7/2		71592.140(17)	0.26		
11/2	9/2		71592.140(17)	0.33		
5/2	3/2		71592.457(21)	0.14		
7/2	5/2		71592.457(21)	0.19		
5	4		89489.226(30)		8.95	
11/2	9/2		89489.169(31)	0.26		
13/2	11/2		89489.169(31)	0.32		
7/2	5/2		89489.356(33)	0.17		
9/2	7/2		89489.356(33)	0.21		
6	5		107385.528(55)		12.53	
13/2	11/2		107385.486(56)	0.26		

Table 6. Microwave Spectrum of $^{28}Si^{33}S$ (continued)

Transition Upper State J' F'	Lower State J" F"	Observed Frequency (Est. Unc.) MHz	Calculated Frequency[a] (Est. Unc.) MHz	Relative Intensity	Energy Levels (cm^{-1}) Upper State	Ref.
15/2	13/2		107385.486(56)	0.31		
9/2	7/2		107385.611(57)	0.18		
11/2	9/2		107385.611(57)	0.22		
7	6		125280.988(90)		16.71	
15/2	13/2		125280.956(91)	0.26		
17/2	15/2		125280.956(91)	0.30		
11/2	9/2		125281.045(91)	0.19		
13/2	11/2		125281.045(91)	0.22		
8	7		143175.465(140)		21.48	
17/2	15/2		143175.440(141)	0.26		
19/2	17/2		143175.440(141)	0.29		
13/2	11/2		143175.507(141)	0.20		
15/2	13/2		143175.507(141)	0.23		
9	8		161068.820(200)		26.85	
19/2	17/2		161068.799(200)	0.26		
21/2	19/2		161068.799(200)	0.29		
15/2	13/2		161068.852(201)	0.21		
17/2	15/2		161068.852(201)	0.23		
10	9		178960.912(280)		32.82	
11	10		196851.600(360)		39.39	
12	11		214740.745(485)		46.55	
13	12		232628.206(600)		54.31	
14	13		250513.843(750)		62.66	
15	14		268397.515(930)		71.62	
16	15		286279.082(1120)		81.17	

[a] The calculated transitions are limited to those with relative intensities greater than 0.05; the relative intensities are based on unity for each rotational transition J' ← J". For transitions with J" > 8 the splitting of the hyperfine doublett is smaller than 50 kHz and it is assumed that such splitting is not observable in a radiotelescope experiment in those high frequencies.

Table 7. Calculated microwave transitions[a] of SiS in order of frequency (MHz)

Calculated Frequency[b]	Isotopic Species	Transition J' - J"	Estimated Uncertainty
17510.646	$^{30}Si^{32}S$	1 - 0	(0.003)
17657.708	$^{28}Si^{34}S$	1 - 0	(0.003)
17821.302	$^{29}Si^{32}S$	1 - 0	(0.003)
17898.407	$^{28}Si^{33}S$	1 - 0	(0.004)
18154.887	$^{28}Si^{32}S$	1 - 0	(0.002)
35021.158	$^{30}Si^{32}S$	2 - 1	(0.006)
35315.280	$^{28}Si^{34}S$	2 - 1	(0.004)
35642.464	$^{29}Si^{32}S$	2 - 1	(0.005)
35796.673	$^{28}Si^{33}S$	2 - 1	(0.005)
36309.629	$^{28}Si^{32}S$	2 - 1	(0.003)
52531.401	$^{30}Si^{32}S$	3 - 2	(0.009)
52972.579	$^{28}Si^{34}S$	3 - 2	(0.006)
53463.349	$^{29}Si^{32}S$	3 - 2	(0.007)
53694.658	$^{28}Si^{33}S$	3 - 2	(0.008)
54464.083	$^{28}Si^{32}S$	3 - 2	(0.004)
70041.242	$^{30}Si^{32}S$	4 - 3	(0.015)
70629.468	$^{28}Si^{34}S$	4 - 3	(0.013)
71283.816	$^{29}Si^{32}S$	4 - 3	(0.013)
71592.223	$^{28}Si^{33}S$	4 - 3	(0.015)
72618.103	$^{28}Si^{32}S$	4 - 3	(0.011)
87550.545	$^{30}Si^{32}S$	5 - 4	(0.028)
88285.810	$^{28}Si^{34}S$	5 - 4	(0.026)
89103.726	$^{29}Si^{32}S$	5 - 4	(0.026)
89489.226	$^{28}Si^{33}S$	5 - 4	(0.030)
90771.546	$^{28}Si^{32}S$	5 - 4	(0.025)
105059.176	$^{30}Si^{32}S$	6 - 5	(0.049)
105941.470	$^{28}Si^{34}S$	6 - 5	(0.048)
106922.941	$^{29}Si^{32}S$	6 - 5	(0.048)
107385.528	$^{28}Si^{33}S$	6 - 5	(0.055)
108924.267	$^{28}Si^{32}S$	6 - 5	(0.049)
122567.002	$^{30}Si^{32}S$	7 - 6	(0.080)
123596.310	$^{28}Si^{34}S$	7 - 6	(0.080)
124741.322	$^{29}Si^{32}S$	7 - 6	(0.080)
125280.988	$^{28}Si^{33}S$	7 - 6	(0.090)
127076.121	$^{28}Si^{32}S$	7 - 6	(0.082)
140073.887	$^{30}Si^{32}S$	8 - 7	(0.122)
141250.194	$^{28}Si^{34}S$	8 - 7	(0.122)
142558.728	$^{29}Si^{32}S$	8 - 7	(0.124)
143175.465	$^{28}Si^{33}S$	8 - 7	(0.140)
145226.965	$^{28}Si^{32}S$	8 - 7	(0.128)
157579.698	$^{30}Si^{32}S$	9 - 8	(0.177)
158902.985	$^{28}Si^{34}S$	9 - 8	(0.178)
160375.021	$^{29}Si^{32}S$	9 - 8	(0.181)
161068.820	$^{28}Si^{33}S$	9 - 8	(0.200)
163376.653	$^{28}Si^{32}S$	9 - 8	(0.186)
175084.300	$^{30}Si^{32}S$	10 - 9	(0.246)
176554.548	$^{28}Si^{34}S$	10 - 9	(0.248)
178190.062	$^{29}Si^{32}S$	10 - 9	(0.252)
178960.912	$^{28}Si^{33}S$	10 - 9	(0.280)
181525.043	$^{28}Si^{32}S$	10 - 9	(0.260)
192587.559	$^{30}Si^{32}S$	11 - 10	(0.330)
194204.744	$^{28}Si^{34}S$	11 - 10	(0.334)
196003.712	$^{29}Si^{32}S$	11 - 10	(0.340)
196851.600	$^{28}Si^{33}S$	11 - 10	(0.360)
199671.988	$^{28}Si^{32}S$	11 - 10	(0.352)
210089.341	$^{30}Si^{32}S$	12 - 11	(0.433)
211853.438	$^{28}Si^{34}S$	12 - 11	(0.438)
213815.832	$^{29}Si^{32}S$	12 - 11	(0.445)
214740.745	$^{28}Si^{33}S$	12 - 11	(0.485)
217817.345	$^{28}Si^{32}S$	12 - 11	(0.461)
227589.511	$^{30}Si^{32}S$	13 - 12	(0.554)
229500.493	$^{28}Si^{34}S$	13 - 12	(0.561)
231626.282	$^{29}Si^{32}S$	13 - 12	(0.570)
232628.206	$^{28}Si^{33}S$	13 - 12	(0.600)
235960.969	$^{28}Si^{32}S$	13 - 12	(0.591)
245087.934	$^{30}Si^{32}S$	14 - 13	(0.695)
247145.773	$^{28}Si^{34}S$	14 - 13	(0.704)
249434.923	$^{29}Si^{32}S$	14 - 13	(0.716)
250513.843	$^{28}Si^{33}S$	14 - 13	(0.750)
254102.716	$^{28}Si^{32}S$	14 - 13	(0.743)
262584.478	$^{30}Si^{32}S$	15 - 14	(0.854)
264789.140	$^{28}Si^{34}S$	15 - 14	(0.870)
267241.616	$^{29}Si^{32}S$	15 - 14	(0.885)
268397.515	$^{28}Si^{33}S$	15 - 14	(0.930)
272242.442	$^{28}Si^{32}S$	15 - 14	(0.918)
280079.006	$^{30}Si^{32}S$	16 - 15	(1.045)
282430.459	$^{28}Si^{34}S$	16 - 15	(1.060)
285046.223	$^{29}Si^{32}S$	16 - 15	(1.079)
286279.082	$^{28}Si^{33}S$	16 - 15	(1.120)
290380.002	$^{28}Si^{32}S$	16 - 15	(1.119)
297571.386	$^{30}Si^{32}S$	17 - 16	(1.267)

---

[a] Only transitions of the ground vibrational state are listed.

[b] For the isotope $^{28}Si^{33}S$ the hypothetical center frequencies are given.

2.3. SiS References

a. Laboratory References

[65A] Hoeft, J., Z. Naturforsch. **20a,** 1327 (1965) "Das Mikrowellenrotationsspektrum des SiS".

[69A] Hoeft, J., Lovas, F. J., Tiemann, E., and Törring, T., Z. Naturforsch. **24a,** 1422 (1969) "Elektrisches Dipolmoment und Mikrowellenrotationsspektrum von SiS".

[72A] Tiemann, E., Renwanz, E., Hoeft, J., and Törring, T., Z. Naturforsch. **27a,** 1566 (1972) "Isotopieeffekte im Rotationsspektrum des SiS".

[73A] Honerjäger, R., and Tischer, R., Z. Naturforsch. **28a,** 1374 (1973) "g_J-Faktor der Molekeln GeO und SiS und Anisotropie ihrer Magnetisierbarkeit".

[70A] Hoeft, J., Lovas, F. J., Tiemann, E., and Törring, T., J. Chem. Phys. **53,** 2736 (1970) "Dipole Moments and Hyperfine Structure of the Group IV/VI Diatomic Molecules".

[69B] Murty, A. N., and Curl, R. F., Jr., J. Mol. Spectr. **30,** 102 (1969) "Dipole Moments of the Sulfides of Pb, Sn, and Si from Stark Effect Measurements".

b. Interstellar Reference

Morris, M., Gilmore, W., Palmer, P., Turner, B. E., and Zuckerman, B., Astrophys. J. **199,** L47 (1975) "Detection of Interstellar SiS and a Study of the IRC +10216 Molecular Envelope".