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THE CALCULATION OF MILLIMETER AND SUBMILLIMETER WAVE
ABSORPTION LINE PARAMETERS FOR THE MOLECULAR OXYGEN
ISOTOPES: $(^{16}\text{O})_2$, $(^{16}\text{O})(^{18}\text{O})$, AND $(^{18}\text{O})_2$

M. Greenebaum

Riverside Research Institute

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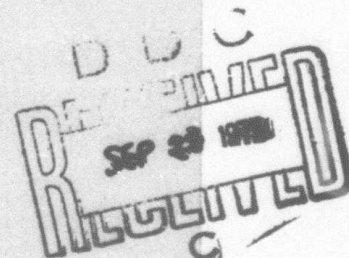
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TECHNICAL REPORT T-1/306-3-14

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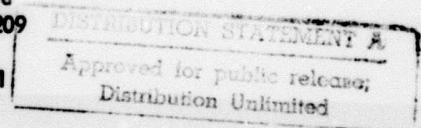
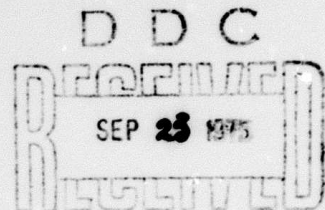
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program (described elsewhere) which calculates the attenuation vs. altitude at any fixed frequency in the millimeter-to-submillimeter wave region.

The calculations were performed on the XDS Sigma 9 computer at RRI by means of APL programs which are listed and explained in the report. Several sets of published molecular constants were used to obtain an estimate of the degree of reliability of the resulting line parameters. Appendices include the predicted transition frequencies, transition moments, and lower state energies for each set of molecular constants employed; tabulations of rotational state sums vs. temperature; line parameters for each of the three isotopes studied, separately; and a list of the 318 absorption lines below 300 cm^{-1} whose strengths exceed 3.7 E-30 cm^{-1} per molecule cm^{-2} at 296K.

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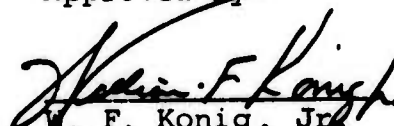
This report describes work performed at Riverside Research Institute by M. Greenebaum with the assistance of D. Koppel and S. Rosenberg. The report was written by M. Greenebaum.

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ABSTRACT

Calculations are described which yield absorption line parameters for the three isotopes of molecular oxygen: $^{16}\text{O}_2$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}_2$, in the format of the AFCRL Atmospheric Absorption Line Parameters Compilation. The line parameters are: transition frequency, integrated line strength at 296K, line width, lower-state energy, and identifying quantum numbers. These parameters are required as input to the SLAM program described elsewhere which calculates the attenuation vs. altitude at any fixed frequency in the millimeter-to-submillimeter wave region.

The calculations were performed on the XDS Sigma 9 computer at RRI by means of APL programs which are listed and explained in the report. Several sets of published molecular constants were used to obtain an estimate of the degree of reliability of the resulting line parameters. Appendices include the predicted transition frequencies, transition moments, and lower state energies for each set of molecular constants employed; tabulations of rotational state sums vs. temperature; line parameters for each of the three isotopes studied, separately; and a list of the 318 absorption lines below 300 cm^{-1} whose strengths exceed 3.7 E-30 cm^{-1} per molecule cm^{-2} at 296K.

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THE CALCULATION OF MILLIMETER AND SUBMILLIMETER WAVE ABSORPTION LINE PARAMETERS FOR THE MOLECULAR OXYGEN ISOTOPES: $^{16}\text{O}_2$, $^{16}\text{O}^{18}\text{O}$, AND $^{18}\text{O}_2$

Introduction

This Technical Report describes a portion of the calculations performed at RRI on the atmospheric propagation characteristics of electromagnetic radiation of millimeter and submillimeter wavelengths. The calculations described here are those of a set of absorption line parameters for three isotopes of molecular oxygen: $^{16}\text{O}_2$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}_2$. These line parameters are required by the SLAM program (described in a separate Tech. Report) to calculate the attenuation vs. altitude at any fixed frequency in the covered wavelength region. The line parameters are: frequency (cm^{-1}), strength at 296K (cm^{-1} per molecule per cm^2), linewidth (cm^{-1} per atm), and lower state energy (cm^{-1}) for each transition, labelled by the appropriate quantum numbers, date of calculation (month, year), isotope, and species (7 for oxygen). The calculations were done on the basis of several sets of published molecular constants¹⁻⁷ by means of AFL programs written for the XDS Sigma 9 computer at RRI. The programs are listed and explained in this report.

The succeeding sections of this report discuss the molecular theory of the oxygen molecule, the calculation of line positions, lower state energies, and integrated line strengths, evaluation of line widths, and the format of the line parameters listed in the Appendices. In addition to the line parameter listings (for all isotopes except $^{16}\text{O}^{17}\text{O}$), the Appendices contain the following:

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a brief summary of APL notational conventions, predictions of transition frequencies and lower state energies to 9-digit accuracy (both in GHz and in cm^{-1}) for each set of molecular parameters employed, a tabulation of rotational state sums vs. temperature, and several other listings of general interest, but not required in the body of the report.

Molecular Theory of the Oxygen Isotopes

The first essentially correct theoretical treatment of the fine structure of the molecular oxygen ground state was that of Tinkham and Strandberg.¹ This theory (applicable to $^{16}\text{O}_2$ and $^{18}\text{O}_2$) predicted that, in addition to the well-known microwave spectrum, oxygen also possessed a "forbidden" submillimeter spectrum, and made predictions of the line strengths. The essential correctness of the theory (with the exception of the strength prediction for one type of "forbidden" transition) was shown by Gebbie, et al.,⁸ on the basis of laboratory measurements at low resolution, as well as by the observation of atmospheric absorption at high altitudes using the Sun as a source.^{9,10} In his recent thesis, Steinbach has succeeded in clarifying the theory with the aid of the transformation theory for spherical tensor operators,¹¹ and it is based on Steinbach's formulation that the RRI calculations of line strengths have been performed, especially since it places $^{16}\text{O}^{18}\text{O}$ on an equal footing with the homonuclear isotopes.^{7,11}

The basic physical features are as follows: None of the oxygen molecular isotopes possess a permanent electric dipole moment. For the $^{16}\text{O}_2$ and $^{18}\text{O}_2$ isotopes, this follows from the homonuclear symmetry, whereas for $^{16}\text{O}^{18}\text{O}$ (as well as $^{16}\text{O}^{17}\text{O}$), this is an experimental fact.¹¹ The electronic ground state being $^3\Sigma_g^-$, the average (electronic) orbital angular momentum vanishes ($\Lambda = 0$)--although there is an instantaneous non-zero value of the orbital angular momentum which produces a precessing magnetic dipole moment of orbital origin. Since the electronic

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ground state is a triplet state, the total electronic spin is $S = 1$, so that molecular oxygen has a permanent magnetic dipole moment of approximately two Bohr magnetons.¹ The oxygen molecule interacts via this dipole moment with the magnetic field associated with an electromagnetic wave. It has been noted by several authors^{1,11,12} that oxygen is capable of very strong atmospheric absorption of electromagnetic radiation despite the weakness of magnetic dipole transitions relative to electric dipole transitions (by two or more orders of magnitude, in general) by virtue of its abundance (21% by volume of air at "all" altitudes). (By way of contrast, water, with the large electric dipole moment of 1.9 Debye units, decreases rapidly in concentration with altitude above 3 km.)

As is typical for microwave and submillimeter wave absorption, the molecular oxygen absorption frequencies in this region are associated with changes in the rotational energy of the molecule, with no change taking place either of the vibrational or of the electronic state. (At room temperature, both the ground vibrational state and the first excited vibrational state are significantly populated and are taken into account in these calculations.) The energy in any given rotational state is the sum of three terms: the pure-rotation term, $H_{\text{rot}} = B\vec{N}^2$ (where $\vec{N}$ is the rotational angular momentum operator describing end-over-end rotations of the molecule, and B is the rotational parameter--itself a function of N when "stretching", i. e., rotation-vibration interaction, is taken into account); a spin-rotation (or spin-orbit¹) term, $H_{\text{s-r}} = \mu\vec{N}\cdot\vec{S}$ (where $\vec{S}$ is the total electron spin operator, and μ is the spin-rotation coupling parameter--likewise N -dependent under centrifugal stretching); and a spin-spin term, $H_{\text{s-s}} = (2/3)\lambda(3S_z^2 - \vec{S}^2)$ (where S_z is the body-fixed component of $\vec{S}$ along the internuclear axis of the molecule, and λ is the spin-spin interaction parameter, comparable in magnitude to B). A spectroscopic convention is followed here: not only frequencies, but also energies and rotational,

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spin-rotation and spin-spin interaction parameters, are expressed in frequency units: GHz or cm^{-1} . Note that the speed of light is $29.9792458(1.2)$ GHz per cm^{-1} ,¹³ so that $1 \text{ cm}^{-1} \approx 30 \text{ GHz}$.

Since the nuclear spins of ^{16}O and of ^{18}O are zero ($I = 0$), no hyperfine energy term appears in the Hamiltonian. For ^{17}O , however, $I = 5/2$, enormously complicating the spectrum of $^{16}\text{O}^{17}\text{O}$ relative to that of $^{16}\text{O}^{18}\text{O}$, $^{16}\text{O}_2$, or $^{18}\text{O}_2$.¹⁴⁻¹⁶ The hyperfine spectrum of $^{16}\text{O}^{17}\text{O}$ (as well as the Zeeman effect in the presence of a d-c magnetic field, for all isotopes¹¹) will be treated in another Technical Report,¹⁷ based on some results by Steinbach.¹⁶ The relative abundances of the various isotopic species of molecular oxygen are given in Table I.

Therefore, restricting our attention to oxygen molecules with $I = 0$, there are only three angular momentum operators to consider: $\vec{N}$, the rotational angular momentum, $\vec{S}$, the spin angular momentum, and $\vec{J} = \vec{N} + \vec{S}$, the total angular momentum. $\vec{J}$ enters because the spin-rotation term may be rewritten as a function of $\vec{N}^2$, $\vec{S}^2$, and $\vec{J}^2$ alone, since $\vec{N} \cdot \vec{S} = (1/2)(\vec{N}^2 + \vec{S}^2 - \vec{J}^2)$. As is well-known,^{1,8,12,18} the ordinary microwave absorption spectrum of $^{16}\text{O}_2$ can be explained to a good first approximation by assuming the spin tightly coupled to the rotation in a pure Hund's case (b) fashion. However, such a coupling scheme fails to predict the existence of the submillimeter absorption lines and also fails to reproduce all the details of the observed microwave spectrum.^{1,19} Consequently, Tinkham and Strandberg performed the energy calculations in a Hund's case (a) basis (in which J , N , S , and M_S are good quantum numbers) and transformed to a Hund's case (b) basis (in which J , M_J , N , and S are good quantum numbers).¹ The calculations are fairly involved, and the expressions needed to calculate transition strengths contain typographical errors, but (with the exception noted by Gebbie et al,⁸ and independently by Steinbach¹¹) their numerical values for the transition matrix elements (line strengths)

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Table I: Relative Abundances of the Isotopes of O₂

<u>Isotopic Species</u>	<u>Relative Abundance</u> ^a
¹⁶ O ¹⁶ O	0.99519
¹⁶ O ¹⁸ O	4.07·10 ⁻³
¹⁶ O ¹⁷ O	7.38·10 ⁻⁴
¹⁸ O ¹⁸ O	4.16·10 ⁻⁶
¹⁷ O ¹⁸ O	1.51·10 ⁻⁶
¹⁷ O ¹⁷ O	1.37·10 ⁻⁷

^a Based upon the following isotopic abundances of atomic oxygen:
¹⁶O: 99.759%, ¹⁷O: 0.037%, ¹⁸O: 0.204%

Reference: Handbook of Chemistry and Physics, 52nd Edition,
1971-1972, Chemical Rubber Co., Cleveland, Ohio.

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agree with those of later workers.¹¹ A different approach has been taken by Steinbach^{7,11} based on earlier (but incorrect^{1,3}) calculations by Hill and Mizushima.¹⁹ In this approach, all calculations are carried out in a Hund's case (b) basis, and one finds the matrix elements of S_z in this basis. Steinbach¹¹ performed the calculations by using the theory of irreducible tensor operators as summarized by Cook and DeLucia¹² to obtain explicit algebraic expressions for the eigenvectors describing the stationary energy states:

$$|\psi\rangle = \alpha |J, M_J, N=J-1, S\rangle + \beta |J, M_J, N=J, S\rangle + \gamma |J, M_J, N=J+1, S\rangle, \quad \dots(1)$$

in terms of the three parameters, α , β , and γ , using the Wigner 6-j symbols. The fact that (with one exception) either α or γ is nearly 1 while the other is almost (but not quite) zero¹¹ means that oxygen is "almost" Hund's case (b), but that N has ceased to be a "good quantum number" except for "diagonal" states (corresponding to $\alpha_0 = \gamma_0 = 0$, $\beta_0 = 1$ in Steinbach's notation¹¹), as noted earlier by Mizushima and colleagues^{3,4,6,19} and by Tinkham and Strandberg.¹ In these calculations, the molecular rotational, spin-spin, and spin-rotation parameters, B , λ , and μ , are assumed to depend as follows on N and J :^{3,6,11,19}

$$\left. \begin{aligned} B &= B_0 + B_1 N(N+1) + B_2 N^2(N+1)^2 + \dots \\ \lambda &= \lambda_0 + \lambda_1 N(N+1) + \dots \\ \mu &= \mu_0 + \mu_1 N(N+1) + \dots \end{aligned} \right\} \begin{array}{l} \text{for } N = N' \\ \text{matrix elements,} \end{array}$$

$$\lambda = \lambda_0 + \lambda_1 (J^2 + J + 1) + \dots \quad \begin{array}{l} \text{for } N \neq N', N = J \pm 1 \\ \text{matrix elements.} \end{array}$$

...(2)

The seven parameters, B_0 , B_1 , B_2 , λ_0 , λ_1 , μ_0 , and μ_1 are obtained by fitting observed transition frequencies to the model Hamiltonian,¹⁻⁷ supplemented by calculations of the isotopic

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dependence¹⁸ of these parameters, where required.^{7,11,21} The separation between the lowest rotational levels in the ground vibrational state ($v = 0$) and in the first excited vibrational state ($v = 1$), denoted by $\Delta G_{1/2}$ by Herzberg,^{18,21} is taken to be $1556.378(7) \text{ cm}^{-1}$, based upon the re-evaluation by Albritton, et al⁵ of electron optical²¹ and microwave^{3,4} data.

These parameters, as given by Refs. 1 through 7, have been inserted into APL "functions" (programs) such as PARAMSTEIN, listed in Fig. 1. A brief description of the APL programming language is contained in Appendix A. In Appendix B, the parameters are explicitly given, together with the transition matrix elements, transition frequencies, etc., calculated from them as discussed in the ensuing sections. Listings of two similar APL parameter-setting programs used in the RRI calculations, PARAMSTEINUPPER and PARAMETERS, are given in Appendix C.

The parameters quoted for Tinkham and Strandberg¹ are based on the correspondences: $B_{(0)T-S} = B_0$, $4\epsilon^2 B_{(0)T-S} = B_1$, $B_2 = 0$, $\lambda_{(0)T-S} = \lambda_0$, $4\epsilon^2 \lambda_{1T-S} = \lambda_1$, $\mu_{0T-S} = \mu_0$, $\mu_1 = 0$. (See Ref. 1, footnote 41.) The parameters quoted for Albritton, et al⁵ are based on electronic optical data²¹ for $v = 0$, and on ground-state microwave data^{3,4} and upper-state electronic optical data²¹ for $v = 1$. (See Ref. 5, p. 116, Table IX.)

Line Positions and Lower State Energies

Except for an arbitrary additive constant, the eigenvalues of the Hamiltonian operator in the stationary states $|\psi_i\rangle$ are the allowed energy levels. (Different authors^{1,3,5} choose different additive constants.) We follow the calculational scheme of Mizushima, et al,^{3,4,6} and Steinbach and Gordy^{7,11} in which the eigenvalues are obtained by solving the secular determinantal equations:

$$|H_{11} - E| = 0, \quad H_{11} = \langle J=0, M_J, N=1, S | H | 0, M_J, 1, S \rangle, \dots (3a)$$

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```

      ▽ PARAMSTEIN;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1
[1]  * 'REFNO' IS 7, CORRESPONDING TO W. STEINBACH AND W. GORDY, PHYS.
[2]  * REV. A, VOL. 11, NO. 3, PP. 729 TO 731, MARCH 1975.
[3]  VECB0←43.10046 40.707408 38.31373
[4]  VECB1←0.00014501 0.000129 0.000115
[5]  VECB2←0 0 0
[6]  VECLAM0←59.501341 59.499097 59.496698
[7]  VECLAM1←5.848E-5 5.312E-5 5.211E-5
[8]  VECMU0←0.252586 0.238489 0.224439
[9]  VECMU1←2.47E-7 6.19E-7 3.51E-7
[10] REFNO←7
[11] ISO←66 68 88
[12] ISOTEXT←3 70 ' '
[13] ISOTEXT[1;]←'O16=O16';ISOTEXT[2;]←'O16=O18';ISOTEXT[3;]←'O18=O18'
[14] INPUT:'PLEASE TYPE ISOTOPE CODE: 66, 68, OR 88'
[15] X←ISO[1]
[16] →(X>0 ISO)/INPUT
[17] B0←VECB0[X]
[18] B1←VECB1[X]
[19] B2←VECB2[X]
[20] LAM0←VECLAM0[X]
[21] LAM1←VECLAM1[X]
[22] MU0←VECMU0[X]
[23] MU1←VECMU1[X]
[24] '

THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR ';ISOTEXT[X;]':

'
[25] 'B0 = ';B0;' GHZ; '
[26] 'B1 = ';B1;' GHZ; '
[27] 'B2 = ';B2;' GHZ;
'
[28] 'LAM0 = ';LAM0;' GHZ; '
[29] 'LAM1 = ';LAM1;' GHZ;
'
[30] 'MU0 = ';MU0;' GHZ; '
[31] 'MU1 = ';MU1;' GHZ.
'
[32] TEMP←296
[33] 'TEMP = ';TEMP;' REFNO = ';REFNO;' ISOTOPE = ';ISO[X]
[34] NINPUT←1+2*(127)
[35] →(X≠2)/0
[36] NINPUT←1+140
      ▽

```

Fig. 1: Listing of APL function PARAMSTEIN

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$$\begin{vmatrix} a-E & 0 & d \\ 0 & b-E & 0 \\ d & 0 & c-E \end{vmatrix} = 0, \text{ where } J \neq 0, \text{ and,} \quad \dots(3b)$$

under the simplifying assumption^{4-7, 11} that $B_2 = 0$,

$$\begin{aligned} a &= \langle J, M_J, N=J-1, S | H | J, M_J, N=J-1, S \rangle \\ &= B_0 J(J-1) + B_1 J^2(J-1)^2 + \mu_0(J-1) + \mu_1 J(J-1)^2 \\ &\quad + \left[(2/3) - 2J/(2J+1) \right] \left[\lambda_0 + \lambda_1 J(J-1) \right], \end{aligned}$$

$$\begin{aligned} b &= \langle J, M_J, N=J, S | H | J, M_J, N=J, S \rangle \\ &= B_0 J(J+1) + B_1 J^2(J+1)^2 - \mu_0 - \mu_1 J(J+1) \\ &\quad + (2/3) \left[\lambda_0 + \lambda_1 J(J+1) \right], \end{aligned}$$

$$\begin{aligned} c &= \langle J, M_J, N=J+1, S | H | J, M_J, N=J+1, S \rangle \\ &= B_0(J+1)(J+2) + B_1(J+1)^2(J+2)^2 - \mu_0(J+2) - \mu_1(J+1)(J+2)^2 \\ &\quad + \left[(2/3) - 2(J+1)/(2J+1) \right] \left[\lambda_0 + \lambda_1(J+1)(J+2) \right], \text{ and} \end{aligned}$$

$$\begin{aligned} d &= \langle J, M_J, N=J+1, S | H | J, M_J, N=J-1, S \rangle \\ &= 2 \sqrt{J(J+1)} (2J+1)^{-1} \left[\lambda_0 + \lambda_1(J^2+J+1) \right]. \quad \dots(3c) \end{aligned}$$

In terms of a , b , c , and d , the energy eigenvalues and the corresponding eigenvector coefficients α , β , and γ in Eq. (1) are given by:¹¹

$$\begin{aligned} H_{11} &= 2(B_0 + 2B_1) - 2(\mu_0 + 2\mu_1) - (4/3)(\lambda_0 + 2\lambda_1), \\ \alpha_{11} &= \beta_{11} = \gamma_{11} = 0; \quad \dots(4a) \end{aligned}$$

$$E_0(J) = b, \quad \alpha_0 = 0, \beta_0 = 1, \gamma_0 = 0; \quad \dots(4b)$$

$$\begin{aligned} E_{\pm}(J) &= (1/2)(a+c) \pm \sqrt{(1/4)(a-c)^2 + d^2}, \\ \alpha_{\pm} &= d / \sqrt{(a-E_{\pm})^2 + d^2}, \beta_{\pm} = 0, \gamma_{\pm} = \alpha_{\pm}(E_{\pm} - a)/d. \quad \dots(4c) \end{aligned}$$

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Eqs. (3) and (4) are contained within the APL program ABCD (lines 11-36 in Fig. 7, p. 24). (This program computes the transition matrix elements, as discussed in a later section.)

More generally, for $B_2 \neq 0$, the energy levels are given by Eqs. (5) of Ref. 3, as corrected by Steinbach⁷ and Mizushima²²:

$$E(J=N=n) = B_0 n(n+1) + B_1 n^2(n+1)^2 + B_2 n^3(n+1)^3 + 2\lambda_0/3 + 2\lambda_1 n(n+1)/3 - \mu_0 - \mu_1 n(n+1), \quad \dots(5a)$$

$$\begin{aligned} E(J=n-1) = & B_0(n^2-n+1) + B_1(n^4-2n^3+7n^2-6n+2) \\ & + B_2(n^6-3n^5+18n^4-31n^3+33n^2-18n+4) - \lambda_0/3 \\ & - \lambda_1(n^2-n+4)/3 - 3\mu_0/2 - \mu_1(7n^2-7n+4)/2 \\ & + \left[B_0(2n-1) + B_1(4n^3-6n^2+6n-2) \right. \\ & \quad + B_2(6n^5-15n^4+32n^3-33n^2+18n-4) - \lambda_0/(2n-1) \\ & \quad - \lambda_1(7n^2-7n+4)/(6n-3) - \mu_0(2n-1)/2 \\ & \quad \left. - \mu_1(2n^3-3n^2+9n-4)/2 \right]^2 \\ & \quad + 4 \left[\lambda_0 + \lambda_1(n^2-n+1) \right]^2 n(n-1)/(2n-1)^2 \Big]^{1/2}, \quad \dots(5b) \end{aligned}$$

$$\begin{aligned} E(J=n+1) = & B_0(n^2+3n+3) + B_1(n^4+6n^3+19n^2+30n+18) \\ & + B_2(n^6+9n^5+48n^4+153n^3+279n^2+270n+108) - \lambda_0/3 \\ & - \lambda_1(n^2+3n+6)/3 - 3\mu_0/2 - \mu_1(7n^2+21n+18)/2 \\ & - \left[B_0(2n+3) + B_1(4n^3+18n^2+30n+18) \right. \\ & \quad + B_2(6n^5+45n^4+152n^3+279n^2+270n+108) \\ & \quad - \lambda_0/(2n+3) - \lambda_1(7n^2+21n+18)/(6n+9) \\ & \quad \left. - \mu_0(2n+3)/2 - \mu_1(2n^3+9n^2+21n+18)/2 \right]^2 \\ & \quad + 4 \left[\lambda_0 + \lambda_1(n^2+3n+3) \right]^2 (n+1)(n+2)/(2n+3)^2 \Big]^{1/2}. \quad \dots(5c) \end{aligned}$$

where n (denoted ' n ' by Steinbach¹¹ and K by Tinkham¹) is an

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"effective³ (or pseudo¹¹) quantum number" such that $n \rightarrow N$ in the limit, $\lambda/B \rightarrow 0$. In the APL program GENGHZ, listed in Fig. 2, Eqs. (5) are used to compute the energy levels, $ENN = E(J=n) = E_0$, $ENNMIN1 = E(J=n-1) = E_+$, and $ENNPLU1 = E(J=n+1) = E_-$, all in gigahertz (GHz).

The microwave transition frequencies, $f^\pm$, are characterized by the selection rules,

$$\Delta K = 0, \Delta J = \pm 1 \text{ (Microwave spectrum)} \quad (6a)$$

and are given by:

$$f^+ = E_0 - E_- = FP = ENN - ENNPLU1 = ENN - ELP \quad (6b)$$

$$f^- = E_0 - E_+ = FM = ENN - ENNMIN1 = ENN - ELM \quad (6c)$$

These frequencies are included in Appendix B (following the output format governed by the APL program PRINT6002), together with the lower state energies, ELP and ELM, relative to the ground state, which is ($K = 1, J = 0$) in $^{16}O_2$ and $^{18}O_2$ and is ($K = 0, J = 1$) in $^{16}O^{18}O$. As is well known,^{18,21} the homonuclear symmetry of $^{16}O_2$ and $^{18}O_2$ permits only odd-K states to exist, whereas two sets of states, one even in K, the other odd in K, exist in $^{16}O^{18}O$.

The program GENINVCN (Fig. 3) converts the energies to the units of cm^{-1} , i. e., $NUNN$, $NUNNMIN1$, and $NUNNPLU1$ are in cm^{-1} relative to the ground state, and $NUNPLU$ and $NUNMIN$ are the transition frequencies in cm^{-1} .

The submillimeter absorption frequencies are characterized by the selection rules,

$$\Delta K = 2, \Delta J = 0, 1 \text{ (Submm spectrum)} \quad (7a)$$

and occur as triplets. With upper states denoted by a single prime (K', J'), and lower states by a double prime (K'', J''), we label the transition frequencies as follows:

```

V GENGHZ2;N;ENJMINUS;ENJPLUS;AB0;AB1;AB2;AL1;AM1;BB1;BB2;BL11;BM0;BM1;MESS0;MESS1;MESS2;ARG1
  THIS PROGRAM IS A CORRECTED VERSION OF EQUS. (5A).
  (5B). AND (5C) OF W. M. WELCH AND M. MIZUSHIMA, PHYS. REV. A,
  VOL. 5, NO. 6, PP. 2692 TO 2695, JUNE 1972. E(J=N=N) IS HERE
  LABELLED AS ENN; E(J=N-1) IS HERE LABELLED ENNMIN1; AND
  E(J=N+1) IS HERE LABELLED ENNPLU1.
  WITH B0, B1, B2, LAM0, LAM1, MU0, AND MU1 IN GIGAHERTZ.
  GENGHZ GENERATES AS OUTPUTS THE ENERGY LEVELS,
  ENN, ENNMIN1, AND ENNPLU1, IN GIGAHERTZ.
  B1+--(|B1)
  B2+--(|B2)
  MU0+--(|MU0)
  MU1+--(|MU1)
  N=NINPUT, (NINPUT+2)
  ENJ+-(B0*N*(N+1))+(B1*(N*2)*((N+1)*2))+(2*LAM0/3)+(2*LAM1*N*(N+1)/3)-(MU0+(MU1*N*(N+1)))
  ENJ+ENJ+(B2*(N*3)*((N+1)*3))
  ENN+((P*N)/2)+ENJ
  AB0+-(N*2)+1-N
  AB1+-(N*4)+(7*(N*2))+2-((2*(N*3)))+(6*N))
  AB2+-(N*6)+(18*(N*4))+(33*(N*2))+4-((3*(N*5)))+(31*(N*3))+(18*N))
  AL1+-(N*2)+4-N
  AM1+-(7*(N*2))+4-(7*N)
  BB1+-(4*(N*3))+(6*N)-((6*(N*2))+2)
  BB2+-(6*(N*5))+(32*(N*3))+(18*N)-((15*(N*4)))+(33*(N*2))+4)
  BL11+-(6*N)-3
  BM0+N-0.5
  BM1+-(2*(N*3))+(9*N)-((3*(N*2))+4)
  MESS0+-(B0*AB0)+(B1*AB1)+(B2*AB2)-((LAM0/3)+(LAM1*AL1/3)+(3*MU0/2)+(0.5*MU1*AM1))
  MESS1+-(B0*(2*N)-1)+(B1*BB1)-((LAM0/((2*N)-1)))+(LAM1*AM1)/BL11)+(MJO0*BM0)+(0.5*MU1*BM1))
  MESS1+MESS1+(B2*BB2)
  MESS2+-(LAM0)+(LAM1*AB0)
  ARG1+-(MESS1+((4*(MESS2*2)*N*(N-1))*((2*N)-1)*-2))
  ENJMINUS+MESS0+(ARG1*0.5)
  E10+MESS0+MESS1
  ENNMIN1+((P*N)/2)+ENJMINUS
  +(N[1]*0)/CONTINUE
  ENNMIN1[2]+E10[2]
  CONTINUE:ENNMIN1[1]+E10[1]
  ENJPLUS+MESS0-(ARG1*0.5)
  ENNPLU1+((P*N)/2)+ENJPLUS
  +(N[1]*0)/0
  ENN[1]+ENNMIN1[1]+ENNPLU1[1]

```

Fig. 2: Listing of APL function GENGHZ

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```

V GENINVCN
[1]  * THIS FUNCTION GENERATES THE ROTATIONAL ENERGY LEVELS
[2]  * AND MICROWAVE TRANSITION FREQUENCIES IN INVERSE CENTIMETERS.
[3]  * IT CALLS GENGHZ AS A SUBROUTINE, AND CONVERTS TO INVERSE CM
[4]  * BY USING AS THE SPEED OF LIGHT, SPEEDOFLIGHT=29.9792458(1.2)
[5]  * GIGAHERTZ PER INVERSE CENTIMETER (1973 VALUE).
[6]  * THE ENERGY LEVELS ARE CALLED NUNN, NUNNMIN1, AND
[7]  * NUNNPLU1, WHILE THE N+ AND N- TRANSITION FREQUENCIES ARE
[8]  * CALLED NUNPLU AND NUNMIN, RESPECTIVELY. THE 1(0) STATE (FOR
[9]  * WHICH N=1, J=0) IS TAKEN AS THE ZERO ENERGY LEVEL.
[10] * IN THE CASE OF 016=018, THE 0(1) STATE (FOR WHICH
[11] * N=0, J=1) IS TAKEN AS THE ZERO ENERGY LEVEL.
[12] GENGHZ
[13] SPEEDOFLIGHT=29.9792458 (UNITS: GHZ PER INVERSE CM)
[14] +(NINPUT[1]≠0)/CONTINUE
[15] E10[1]=ENNPLU1[1]
[16] CONTINUE:NUNN=(ENN-E10[1])*SPEEDOFLIGHT
[17] NUNNMIN1=(ENNMIN1-E10[1])*SPEEDOFLIGHT
[18] NUNNPLU1=(ENNPLU1-E10[1])*SPEEDOFLIGHT
[19] NUNPLU=NUNN-NUNNPLU1
[20] NUNMIN=NUNN-NUNNMIN1
[21] +(NINPUT[1]≠0)/0
[22] NUNMIN[1]=NUNPLU[1]+NUNN[1]+NUNNMIN1[1]+NUNNPLU1[1]+0
V

```

Fig. 3: Listing of APL function GENINVCN

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$$\text{NUF: } K' = K''+2, \quad J'-1 = J'' = K'' \quad (7b)$$

$$\text{NUG: } K' = K''+2, \quad J' = J'' = K''+1 \quad (7c)$$

$$\text{NUH: } K' = K''+2, \quad J'-1 = J'' = K''+1 \quad (7d)$$

The program SUBMMO2 (Fig. 4) calculates, in cm^{-1} , the transition frequencies, NUF, NUG, and NUH, as well as the respective lower state energies, ELF, ELG, and ELH = ELG, relative to the rotational ground state ($K = 1, J = 0$ for $^{16}\text{O}_2$ and $^{18}\text{O}_2$, $K = 0, J = 1$ for $^{16}\text{O}^{18}\text{O}$). The results of these calculations for the various sets of values of the molecular parameters, B_0, B_1 , etc., are included in Appendix B, together with the equivalents of NUF, NUG, and NUH in GHz.

For the rotational band lying above the first excited vibrational state, the lower state energy relative to the true ground state (for $v = 0$) is given by $\Delta G_{1/2}$ plus the energy relative to the rotational ground state, e. g., ELF. This consideration is important when computing the line strength, and is taken into account in our calculations (via LINESTRENGTHROTVEB, AFCRL5K15UPPER and AFCRL60K1UPPER (see Appendix A)).

In Appendix B, the "laser-magnetic-resonance" or Raman lines studied by Evenson, et al^{4,6} are also listed. These lines are characterized by:

$$\text{ERL: } K' = K''+2, \quad J' = K', \quad J'' = K'' \quad (8)$$

The root-mean-square deviation between the Raman lines observed to date⁶ and the various predicted frequencies is also given in Appendix B. These lines are of no concern in calculations of atmospheric absorption by molecular oxygen.¹⁷

Line Strengths

The general expression for the integrated line strength of an isolated magnetic dipole transition between an initial state, $|\psi_i\rangle$ (lower state in absorption), and a final state, $|\psi_f\rangle$ (upper state in absorption), taking into account both absorption and

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```

V SUBMMO2;N;ENJ;ENJMINUS;ENJPLUS;AB0;AB1;AB2;AL1;AM1;BM1;BB2;BL11;BM0;BM1;MESS0;MESS1;MESS2;ARG1;EDF;EDG;EDH
[1] * THIS PROGRAM CALCULATES THE TRANSITION FREQUENCIES,
[2] * NUF, NUG, AND NUH (IN THE SUBMM REGION), AND THE ENERGIES
[3] * OF THE RESPECTIVE LOWER STATES, ELF, ELG, AND ELH,
[4] * ALL GIVEN IN INVERSE CM. INPUTS REQUIRED: B0, B1, B2,
[5] * LAM0, LAM1, MU0, AND NINPUT.
[6] * (EXAMPLE: NINPUT=((2*1 27)-1) PRODUCES 1 3 5 ...51 53.)
[7] * REFNO = :REFNO
[8] * NINPUT: :NINPUT
[9] B1←-(|B1)
[10] B2←-(|B2)
[11] MU0←-(|MU0)
[12] MU1←-(|MU1)
[13] N←NINPUT,(NINPUT+2)
[14] ENJ←(B0*N*(N+1))+(B1*(N*2)*((N+1)*2))+(2*LAM0*3)+(2*LAM1*N*(N+1)*3)-(MU0*(MU1*N*(N+1)))
[15] ENJMINUS←(B2*(N*3)*((N+1)*3))
[16] ENJPLUS←((N*2)+ENJ
[17] AB0←(N*2)+1-N
[18] AB1←(N*4)+(7*(N*2))+2-((2*(N*3))+(6*N))
[19] AB2←(N*6)+(18*(N*4))+(33*(N*2))+4-((3*(N*5))+(31*(N*3))+(18*N))
[20] AL1←(N*2)+4-N
[21] AM1←(7*(N*2))+4-(7*N)
[22] BM1←(4*(N*3))+(6*N)-((6*(N*2))+2)
[23] BB2←(6*(N*5))+(32*(N*3))+(18*N)-((15*(N*4))+(33*(N*2))+4)
[24] BL11←(6*N)-3
[25] BM0←N-0.5
[26] BM1←(2*(N*3))+(9*N)-((3*(N*2))+4)
[27] MESS0←(B0*AB0)+(B1*AB1)+(B2*AB2)-((LAM0*3)+(LAM1*AL1*3)+(3*MU0*2)+(0.5*MU1*AM1))
[28] MESS1←(B0*((2*N)-1))+(B1*BB1)-((LAM0*((2*N)-1))+(LAM1*AM1)+BL11)+(MU0*BM0)+(0.5*MU1*BM1))
[29] MESS2←MESS1+(B2*BB2)
[30] MESS2←(LAM0)+(LAM1*AB0)
[31] ARG1←(MESS1*2)+(4*(MESS2*2))*N*(N-1)*(((2*N)-1)*^2)
[32] ENJMINUS←MESS0+(ARG1*0.5)
[33] E10←MESS0+MESS1
[34] ENNMIN1←((N*2)+ENJMINUS
[35] ENNMIN1[1]←E10[1]
[36] ENJPLUS←MESS0-(ARG1*0.5)
[37] ENNPLUS1←((N*2)+ENJPLUS
[38] * EDF, EDG, AND EDH ARE IN GIGAHERTZ
[39] EDF←(((N*2)+ENJMINUS)-ENN
[40] EDG←(((N*2)+ENJMINUS)-ENNPLUS1
[41] EDH←(((N*2)+ENJ)-ENNPLUS1
[42] +(N[1]=0)/CONTINUE
[43] ENNMIN1[2]←E10[2]
[44] E10[1]←ENN[1]-ENNMIN1[1]-ENNPLUS1[1]
[45] EDF[1]←0
[46] CONTINUE:SPEEDOFLIGHT←29.9792458* [GHZ PER INVERSE CM]
[47] * ELF, ELG, ELH, NUF, NUG, AND NUH ARE IN INVERSE CM.
[48] ELF←(ENN-E10[1])*SPEEDOFLIGHT
[49] ELG←(ENNPLUS1-E10[1])*SPEEDOFLIGHT
[50] ELH←ELG
[51] NUF←EDF*SPEEDOFLIGHT
[52] NUG←EDG*SPEEDOFLIGHT
[53] NUH←EDH*SPEEDOFLIGHT

```

Fig. 4: Listing of APL function SUBMMO2

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stimulated emission under equilibrium conditions at (Kelvin) temperature T , is as follows, in units of $\text{cm}^{-1}(\text{molecule cm}^{-2})^{-1}$:

$$S(T) = \frac{8\pi^3}{3hc} \nu_0 |\langle \psi_i | \vec{\mu} | \psi_f \rangle|^2 (e^{-E_i/kT} - e^{-E_f/kT})/Q(T), \quad (9a)$$

where h = Planck's constant = $6.626176(36) \cdot 10^{-27}$ erg sec,
 c = vacuum speed of light = $2.99792458(1.2) \cdot 10^{10}$ cm sec $^{-1}$,
 ν_0 = transition frequency (cm^{-1}),
 E_i = energy of initial (lower) state (ergs),
 E_f = energy of final (upper) state (ergs),
 $Q(T)$ = total partition function (state sum) (dimensionless),
 and the dipole moment operator is summed over all degenerate levels possessing the same initial and final state energies.¹⁸

Rewriting Eq. (9a) in terms of the dimensionless transition strengths, $I(K'', J''; K', J')$,¹ and recalling that $E_f - E_i = hc\nu_0$,

$$S(T) = \frac{8\pi^3}{3hc} (g_s^e \beta_{\text{Bohr}})^2 I(K'', J''; K', J') \nu_0 e^{-E''(hc/kT)} \cdot [1 - e^{-\nu_0(hc/kT)}] / Q(T), \quad (9b)$$

where g_s^e = free-electron g factor = $2 \cdot 1.0011596567(35)$,
 β_{Bohr} = Bohr magneton = $9.274078(36) \cdot 10^{-21}$ erg gauss $^{-1}$,
 hc/k = second radiation constant = $1.438786(45)$ cm K,
 $E'' = E_i/hc$ = lower state energy (cm^{-1}),

$$\text{and } Q(T) = \left[\sum_K (2K+1) \exp(-NUNN \cdot hc/kT) + (2K-1) \exp(-NUNNMIN1 \cdot hc/kT) + (2K+3) \exp(-NUNNPLU1 \cdot hc/kT) \right] \cdot Q_v(T), \quad (10)$$

$$Q_v(T) \triangleq [1 - \exp(-\Delta G_{1/2} \cdot hc/kT)]^{-1} \text{ (p.123, Ref. 18),}$$

since for each value of J , there are $(2J + 1)$ degenerate levels.¹ (Recall that $NUNN = (E_0 - E_{\text{grnd}})/c$, $NUNNMIN1 = (E_+ - E_{\text{grnd}})/c$, and $NUNNPLU1 = (E_- - E_{\text{grnd}})/c$, in the notation of Eqs. (6).¹¹) The values adopted for the fundamental constants are those of Ref. 13. The use of the free-electron g factor is consistent with our neglect of the Zeeman effect;^{1,4,11,17} an error in $S(T)$ of less than 1 part in 10^4 is incurred thereby, while we only require answers correct to three decimal places--to be consistent

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with the accuracy of the AFCRL Atmospheric Absorption Line Parameters Compilation²³ which these computations are intended to supplement.

In the microwave region (but not in the submillimeter wave region), $\nu_0 \ll kT/hc$, so that one may replace the factor in square brackets in Eq. (9b) by its linear approximation, leading to the well-known microwave approximation:^{1,11,12}

$$S(T) \approx \frac{8\pi^3}{3kT} (g_s^e \beta_{\text{Bohr}})^2 I(K'',J'';K',J') \nu_0^2 \frac{\exp(-E''hc/kT)}{Q(T)} \quad (\text{Microwave approximation}) \quad \dots(9c)$$

(Note that in the optical region, the factor in square brackets in Eq. (9b) is approximately unity, i. e., the induced emission term may be neglected at 300K and below, as in Eq. (3) of Ref. 23.)

Choosing $T = T_s = 296K$, the standard temperature of the AFCRL compilation,²³ the thermal energy expressed in wavenumbers is $kT/hc = kT_s/hc = (296)/(1.438786(45)) = 205.729(6) \text{ cm}^{-1}$, so that Eq. (9b) becomes:

$$S(T_s=296K) \approx 1.4353 \cdot 10^{-22} I(K'',J'';K',J') \nu_0 \exp(-E''/205.729) \cdot [1 - \exp(-\nu_0/205.729)] / Q(T_s=296K). \quad \dots(9d)$$

Since we desire our computed line strengths to be consistent with those of AFCRL,²³ we must multiply $S(T_s)$ by the relative isotopic abundance of the molecule (our Table I, or Table 3 of Ref. 23), which is 0.99519 for the dominant isotope, $^{16}\text{O}_2$. Denoting the resulting quantity by $S_m(T_s)$, whose units are cm^{-1} per molecule of mixed oxygen per cm^2 , we obtain an expression like Eq. (9d) with the numerical factor in front replaced by the quantity, $1.4283967 \cdot 10^{-22}$ (retaining extra digits to avoid round-off error) which appears in line 22 of LINESTRENGTH2 (Fig. 5).

The rotational state sum $Q(T)/Q_v(T)$ is evaluated by summing Eq. (10) through $K = 79$ in the program ISOSTATESUM (Fig. 6), and

```

V LINESTRENGTH2
  THIS PROGRAM COMPUTES THE LINE STRENGTHS OF THE MICROWAVE
  AS WELL AS THE SUBMILLIMETER WAVE TRANSITIONS OF MOLECULAR
  OXYGEN. ELP, ELM, FP, AND FM MUST HAVE BEEN CALCULATED (E. G.
  BY 'PRINT6002' OR A CALLING PROGRAM LIKE 'AFCRL60K25').
  THE ROTATIONAL PARTITION FUNCTION, 'SUM', CALCULATED
  BY 'ISOSTATESUM' IS ALSO REQUIRED. THIS PROGRAM CALLS
  'SUBMMO2' TO OBTAIN THE SUBMILLIMETER FREQUENCIES AND
  LOWER STATE ENERGIES. THE MULTIPLICATIVE CONSTANT
  SO, IS THE PRODUCT OF THE RELATIVE ISOTOPIC ABUNDANCE,
   $(8+3) \times ((\pi) \times 3) \times ((\text{MAGNETICMOMENT}) \times 2) \times (\text{HPLANCK} \times \text{SPEED-OF-LIGHT})$ ,
  AND THE RECIPROCAL OF 'SUM', WHERE 'MAGNETICMOMENT' IS THE
  PRODUCT OF THE BOHR MAGNETON AND TWICE THE FREE-ELECTRON G-
  FACTOR, AND HPLANCK IS PLANCK'S CONSTANT.
  KT=205.729*(TEMP+296)
  'TEMP' = 'TEMP'; 'K';      KT = 'KT'; INVERSE CM;      X = 'X'
  SO=1
  +(X=1)/ONE;+(X=2)/TWO;+(X=3)/THREE
  +0; 'INCORRECT VALUE FOUND FOR 'X''; CALL 'PARAMSTEIN'
  NLP+ELP+SPEEDOFLIGHT; NLM+ELM+SPEEDOFLIGHT
  THREE:SO+4.1616E-6+0.00407
  TWO:SO+SO*0.00407+0.99519
  ONE:SO+SO*1.4283967E-22+SUM
  SUBMMO2
  NUF+FP+SPEEDOFLIGHT; NUM+FM+SPEEDOFLIGHT
  NLP+ELP+SPEEDOFLIGHT; NLM+ELM+SPEEDOFLIGHT
  A ELP, ELM, FP AND FM ARE CALCULATED IN 'PRINT6002' AND 'AFCRL60K25'
  SF+SO*F*NUP*(*(-ELF+KT))*((1-*(-NUP+KT)))
  SG+SO*G*NUG*(*(-ELG+KT))*((1-*(-NUG+KT)))
  SH+SO*H*NUH*(*(-ELH+KT))*((1-*(-NUH+KT)))
  SP+SO*PP*NUP*(*(-NLP+KT))*((1-*(-NUP+KT)))
  SM+SO*MM*NUM*(*(-NLM+KT))*((1-*(-NUM+KT)))

```

Fig. 5: Listing of APL function LINESTRENGTH2

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```

V ISOSTATESUM;KT;NINPUT;TERM1;TERM2;TERM3;TERM
[1]  A      THIS PROGRAM COMPUTES THE ROTATIONAL PARTITION FUNCTION
[2]  A OR STATE SUM FOR MOLECULAR OXYGEN. IT IS BASED ON THE ENERGY
[3]  A LEVELS OF STEINBACH AND GORDY. THE PROGRAM SETS TEMP EQUAL
[4]  A TO KELVIN TEMPERATURE TYPED IN RESPONSE TO 'QUAD' ( ) PROMPT.
[5]  A      AT 296K, THE LAST TERM INCLUDED IN THE STATE SUM FOR O16=O16
[6]  A CONTRIBUTES ONLY  $8.06E^{-17}$ ; FOR O16=O18, THE LAST TERM IS  $8.40E^{-16}$ .
[7]  NINPUT+((2*140)-1)
[8]  +(X=2)/SKIP
[9]  NINPUT+(180)-1
[10] SKIP:GENINVCN
[11] 'PLEASE TYPE IN KELVIN TEMPERATURE: '
[12] TEMP+]
[13] KT+205.729*(TEMP+296)
[14] TERM1+(1+2*NINPUT)*(((-NUNN)/KT))
[15] TERM2+(1+2*NINPUT)*(((-NUNNMIN1)/KT))
[16] TERM3+(3+2*NINPUT)*(((-NUNNPLU1)/KT))
[17] +(X=2)/ADD
[18] TERM1[1]+TERM2[1]+0;TERM3[1]+(TERM3[1])*3
[19] ADD:TERM+TERM1+TERM2+TERM3
[20] SUM++/TERM
[21] CLASSICAL+(1.5*KT*SPEEDOFLIGHT)/B0
[22] 'ROTATIONAL STATE SUM = ';SUM;' (EXACT VALUE)'
[23] +(X=2)/BYPASS
[24] 'CLASSICAL APPROXIMATION = (3/2)*(KT/B0)*SPEEDOFLIGHT = ';CLASSICAL
[25] CONTINUE:RATIO+SUM/CLASSICAL
[26] 'RATIO = ';RATIO
[27] 'TEMPERATURE = ';TEMP;'K; ISOTOPE = ';ISOTEXT[X;];'
[28] +0
[29] BYPASS:CLASSICAL+2*CLASSICAL
[30] 'CLASSICAL APPROXIMATION = (3*KT/B0)*SPEEDOFLIGHT = ';CLASSICAL
[31] +(X=2)/CONTINUE
V

```

Fig. 6: Listing of APL function ISOSTATESUM

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compared with the classical values,^{1,12,18} $3kT/2hcB_0$ for $^{16}\text{O}_2$ and $^{18}\text{O}_2$, and $3kT/hcB_0$ for $^{16}\text{O}^{18}\text{O}$. (The state sum contains twice as many rotational states in a heteronuclear diatomic molecule as in a homonuclear one.¹⁸) Appendix D lists some results.

The vibrational partition function $Q_V(T)$ has been approximated by unity at $T = T_s = 296\text{K}$. This is consistent with the AFCRL approximation of $Q_V(T_s) \approx 1.000$ (Table 2, Ref. 23). More precisely, in the harmonic oscillator approximation given by Eq. (10), $[Q_V(T_s=296\text{K})]^{-1} = 1 - \exp(-\Delta G_{1/2} \cdot hc/kT_s)$

$$= 1 - \exp(-1556.378/205.729)$$

$$\approx 1 - 5.1818 \cdot 10^{-4} \approx 0.999482, \quad (11)$$

leading to an overestimate of 5.2 parts in 10^4 in the values for $S_m(T_s)$ as given in this report. Thus, the third decimal place in the line strengths tabulated in this document will be in error by one unit, at most.

We now turn to the calculation of the normalized transition matrix elements (squared), $I(K'',J'';K',J')$, i. e., of the quantities F, G, H, PP, and MM in lines 27-31 of LINESTRENGTH2.

Transition Matrix Elements

Steinbach¹¹ has shown that the normalized magnetic-dipole transition matrix elements, both those for the microwave "fine structure" (or spin-reorientation¹⁸) transitions and those for the "forbidden" submillimeter rotational transitions, may be written in terms of the Wigner 6-j symbols^{20,24} and the eigenvector coefficients, α and γ , appearing in Eqs. (1) and (4). With $n'(J')$ denoting the final state, $n(J)$ the initial state, i. e., employing n instead of K and dropping the double primes, the results are displayed in Table II. These expressions may be simplified further: First, we note that for fixed $J \neq 0$, $\alpha_- = \gamma_+$ and $\alpha_+ = -\gamma_-$ (cf. Tables 8, 9, and 10 of Ref. 11). To prove this formally, let us first note that $d > 0$ from Eq. (3c).

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Table II: Normalized Magnetic Dipole Transition Matrix Elements

Transition $n(J) \rightarrow n'(J')$	Normalized Matrix Element ^a $ \langle \psi_f \vec{\mu} \psi_i \rangle ^2 / (g_s^e \beta_{\text{Bohr}})^2$
---	---

Fine Structure Transitions:

$$n(n-1) \rightarrow n(n): 6(2n-1)(2n+1) \gamma_i^2 \left\{ \begin{matrix} 1 & n & n \\ n-1 & 1 & 1 \end{matrix} \right\}^2$$

$$n(n+1) \rightarrow n(n): 6(2n+1)(2n+3) a_i^2 \left\{ \begin{matrix} 1 & n & n \\ n+1 & 1 & 1 \end{matrix} \right\}^2$$

Rotational Transitions:

$$n(n) \rightarrow n+2 (n+1): 6(2n+1)(2n+3) a_f^2 \left\{ \begin{matrix} 1 & n+1 & n \\ n & 1 & 1 \end{matrix} \right\}^2$$

$$n(n+1) \rightarrow n+2 (n+1): 6(2n+3)^2 \left[a_i a_f \left\{ \begin{matrix} 1 & n+1 & n \\ n+1 & 1 & 1 \end{matrix} \right\} + \gamma_i \gamma_f \left\{ \begin{matrix} 1 & n+1 & n+2 \\ n+1 & 1 & 1 \end{matrix} \right\} \right]^2$$

$$n(n+1) \rightarrow n+2 (n+2): 6(2n+3)(2n+5) \gamma_i^2 \left\{ \begin{matrix} 1 & n+2 & n+2 \\ n+1 & 1 & 1 \end{matrix} \right\}^2$$

^a After Table 2, Ref. 11. The quantities $\left\{ \begin{matrix} j_1 & j_2 & j_3 \\ J_1 & J_2 & J_3 \end{matrix} \right\}$ are Wigner's 6-j symbols (see Ref. 24).

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Letting $(c - a)/2d = \xi$ in Eq. (4c), we find that

$$x_{\pm} \equiv (E_{\pm} - a)/d = \xi \pm \sqrt{1 + \xi^2},$$

so that $x_+ x_- = \xi^2 - 1 - \xi^2 = -1$, and $x_- = -1/x_+$. Letting

$x_+ = \tan \theta$, Eq. (4c) then states that $a_+ = \cos \theta$, $\gamma_+ = a_+ x_+ = \sin \theta$.

Since $x_- = -1/x_+ = -\cot \theta$, Eq. (4c) also states that $a_- = \sin \theta$,

$\gamma_- = a_- x_- = -\sin \theta \cot \theta = -\cos \theta$. Thus, $a_- = \gamma_+$, $a_+ = -\gamma_-$, QED.*

Next, using Eq. (C.36) of Ref. 24 to evaluate the 6-j symbols, we obtain:

$$\left\{ \begin{matrix} 1 & n & n \\ n-1 & 1 & 1 \end{matrix} \right\}^2 = \frac{(n+1)}{6n(2n+1)}; \quad \left\{ \begin{matrix} 1 & n & n \\ n+1 & 1 & 1 \end{matrix} \right\}^2 = \frac{n}{6(n+1)(2n+1)};$$

$$\left\{ \begin{matrix} 1 & n+1 & n \\ n & 1 & 1 \end{matrix} \right\}^2 = \frac{n}{6(n+1)(2n+1)}; \quad \left\{ \begin{matrix} 1 & n+1 & n \\ n+1 & 1 & 1 \end{matrix} \right\} = -\sqrt{\frac{(n+2)}{6(n+1)(2n+3)}};$$

$$\left\{ \begin{matrix} 1 & n+1 & n+2 \\ n+1 & 1 & 1 \end{matrix} \right\} = \sqrt{\frac{(n+1)}{6(n+2)(2n+3)}}; \quad \left\{ \begin{matrix} 1 & n+2 & n+2 \\ n+1 & 1 & 1 \end{matrix} \right\}^2 = \frac{(n+3)}{6(n+2)(2n+5)}.$$

Inserting these results into the expressions in Table II, noting

that $\left[\sqrt{\frac{n+2}{n+1}} + \sqrt{\frac{n+1}{n+2}} \right]^2 = (2n+3)^2(n+1)/(n+2)$, and replacing

n by K once again, we obtain $I(K'', J'', K', J') = \frac{|\langle \psi_f | \vec{\mu} | \psi_i \rangle|^2}{(g_s e \beta_{\text{Bohr}})^2} :$

$$MM = I(K, K-1; K, K) = [\gamma_+(K-1)]^2 (2K-1)(K+1)/K \quad (12)$$

$$PP = I(K, K+1; K, K) = [a_-(K+1)]^2 (2K+3)K/(K+1) \quad (13)$$

$$F = I(K, K; K+2, K+1) = [\gamma_-(K+1)]^2 (2K+3) \cdot K/(K+1) \quad (14)$$

$$G = I(K, K+1; K+2, K+1) = [\gamma_-(K+1)]^2 (2K+3) \cdot [a_-(K+1)]^2 \cdot (2K+3)^2 (K+1)/(K+2) \quad (15)$$

$$H = I(K, K+1; K+2, K+2) = [\gamma_-(K+1)]^2 (2K+3) \cdot (K+3)/(K+2) \quad (16)$$

where the J -dependence of the alphas and gammas in Eqs. (12)-(16) is indicated explicitly by their arguments in parentheses.

* From Eq. (1), it is intuitively clear that θ represents the small (but non-zero) angle in Hilbert space through which $|\psi_{\pm}\rangle$ are rotated away from their Hund's case (b) approximations.

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The equivalents of these six equations are contained in lines 41, 42, 45, and 46 of the program ABCD (Fig. 7). (To avoid possible division by zero, the dyadic APL function $X \text{ REPLACE } Y$ is used. It is listed following ABCD in Fig. 7. It replaces zero values of J and K by a small number during arithmetic operations (ABCD line 10) and, at the end of the calculations (line 41), it undoes the effects of this replacement.)

It is clear from Eqs. (14)-(16) that the submillimeter transitions would be strictly forbidden were γ_- actually zero (pure Hund's case (b) coupling) instead of merely small.¹¹ On the other hand, γ_+ (and a_-) are nearly equal to their case-(b) values of unity; thus, the microwave transitions (Eqs. (12)-(13)) are negligibly affected by the deviation from case (b) coupling.¹ The various types of allowed transitions^{1,7,8,11} are shown in the energy level diagrams of Fig. 8.

The existence of a common factor in Eqs. (14)-(16) not only simplifies the calculation of the strengths of the "forbidden" lines, but also enables us to exhibit the asymptotic behavior of their relative strengths, since $a_-(K+1) \rightarrow 1$ as $K \rightarrow \infty$, i. e., $F : G : H \sim 1 : 4 : 1$. This is in agreement with the correspondence-principle argument of Gebbie, et al.⁸ On the other hand, in their final results (Table VII, column 6, and Eq. (63a)), Tinkham and Strandberg¹ (T-S) incorrectly and "unphysically" predicted "F"-type transitions to be much weaker than "H"-type transitions,⁸ an error carried over into the Russian literature.²⁵ Nevertheless, the intermediate results of T-S (Eqs. (60) and Table V) were essentially correct,¹ as pointed out by Gebbie, et al.⁸ Indeed, one easily deduces that $F : H = K(K+2)/(K+1)(K+3)$ both from our Eqs. (14), (16) as well as from the fifth and eighth of Eqs. (60) of T-S.¹ Thus, except for $I(K, K; K+2, K+1)$, our results for the transition matrix elements, given in Appendix B, are in close agreement with Table V of T-S.¹

To within the tabulated accuracy and limited spectral

```

V ABCD:J,Q:QC:APC:AMC:ROOT:A,B,C,Q:ALPHAG,BETAG,GAMMAG:COMMON
* THIS PROGRAM CALCULATES THE PARAMETERS A, B, C, Q, AND THE VARIOUS ALPHAS, BETAS, AND GAMMAS
* APPEARING IN W. R. STEINBACH'S THESIS, AND USES THEM TO COMPUTE THE TRANSITION MATRIX ELEMENTS
* FOR MOLECULAR OXYGEN. THE OUTPUTS ARE IN THE NOTATION OF TINKHAM AND STRANDBERG, I. E.,
* I(K',J',K',J'). SHORTHAND NOTATION: PP=I(K,K+1;K,K); MM=I(K,K-1;K,K); F=I(K,K;K+2,K+1);
* G=I(K,K+1;K+2,K+1); AND H=I(K,K+1;K+2,K+2). IN ADDITION, ALPHAP, ALPHAM, ALPHA0,
* BETAP, BETAM, BETA0, GAMMAP, GAMMAM, AND GAMMA0 ARE AVAILABLE AS OUTPUT.
* THIS PROGRAM CALLS PARAMSTEIN AS A SUBROUTINE
PARAMSTEIN
J=(K+1),K;K=HINPUT
J+1E-40 REPLACE J;K+1E-40 REPLACE K
Q=J*(J+1)
A=(B0*J*(J-1))+(B1*(J*(J-1)*2))+(MU0*(J-1))+(MU1*J*((J-1)*2))+((2+3)-(2*J+(1+2*J)))*(LAM0+(LAM1*J*(J-1)))
B=(B0*Q)+(B1*Q*2)+((2+3)*(LAM0+LAM1*Q))-(MU0+MU1*Q)
QC=(J+1)*(J+2)
C=(B0*QC)+(B1*QC*QC)+(((2+3)-(2*(J+1)+(1+2*J)))*(LAM0+LAM1*QC))-((MU0*(J+2))+(MU1*QC*(J+2)))
Q=(2*(Q*0.5)+(1+2*J))*(LAM0+(LAM1*Q))
* WE NOW COMPUTE THE EIGENENERGIES AND EIGENVECTOR COEFFICIENTS IN TERMS OF A, B, C, AND Q.
EGRND=(2*(B0+2*B1))-(2*(MU0+(2*MU1)+((2+3)*(LAM0+2*LAM1))))
E0J+E
APC=A+C;AMC=A-C
ROOT=((((AMC*2)+4)+Q*2)*0.5
EPJ=(APC+2)+ROOT;EMJ=(APC+2)-ROOT
* IN THE GROUND STATE, THE FOLLOWING SPECIAL VALUES HOLD:
ALPHAG=0;BETAG=0;GAMMAG=1
* FOR STATES WITH N (= K) = J, ONLY BETA IS NONZERO.
ALPHA0=(P K)P0;BETA0=(P K)P1;GAMMA0=(P K)P0
BETAP=BETAM*(P K)P0
ALPHAP=Q*((A-EPJ)*2)+Q*2)*0.5
ALPHAM=Q*((A-EMJ)*2)+Q*2)*0.5
GAMMAP=ALPHAP*(EPJ-A)+Q
GAMMAM=ALPHAM*(EMJ-A)+Q
* AT THIS POINT, THESE VECTORS ARE NOT YET IN PROPER CORRESPONDENCE TO NINPUT = K. WE NOW
* APPEND THE 'GROUND STATE' VALUES AND THEN MAKE SURE THE DIMENSION IS THE SAME AS THAT OF K.
ALPHAP=(P K)+(ALPHAG,ALPHAP);ALPHAM=(P K)+ALPHAM
BETAP=(P K)+(BETAG,BETAP);BETAM=(P K)+BETAM
GAMMAP=(P K)+(GAMMAG,GAMMAP);GAMMAM=(P K)+GAMMAM
* THE ALPHAS, BETAS, AND GAMMAS ARE GLOBAL VARIABLES (WHICH MAY BE OUTPUT AT WILL).

```

Fig. 7: Listings of the APL functions ABCD and X REPLACE Y

```

[38]      MAKE ARRAYS EOJ, EPJ, AND EMJ CONSISTENT WITH K+1 (=J FOR EPJ, EMJ) OR K (=J FOR EOJ).
[39]      EOJ←(ρK)←B;EPJ←(ρK)←EPJ;EMJ←(ρK)←EMJ
[40]      WE NOW COMPUTE THE TRANSITION MATRIX ELEMENTS, NOTING THAT THE ALPHA AND GAMMA ARRAYS ARE SIMPLY RELATED.
[41]      PP←(ALPHAM*2)*K*(3+2*K)*(K+1)
[42]      MM←(GAMMAP*2)*(K+1)*(-1+2*K)*K
[43]      +(K[1]≥1)/SKIP
[44]      EOJ←(ρK)←(1+EOJ);MM←(ρK)←(0,(GAMMAP*2)*(K+2)*(1+2*K)*(K+1))
[45]      SKIP:COMMON←(GAMMAP*2)*(3+2*K)
[46]      F←COMMON*K*(K+1);G←COMMON*((ALPHAM*(3+2*K))*2)*((K+1)*(K+2));H←COMMON*(K+3)*(K+2)
[47]      K←0 REPLACE K;PP←0 REPLACE PP;MM←0 REPLACE MM;F←0 REPLACE F;G←0 REPLACE G;H←0 REPLACE H
[48]      'K = ' ; K ; '
      ,
[49]      'I(K,K+1;K,K)
      ' ; PP
[50]      'I(K,K-1;K,K)
      ' ; MM
[51]      ,
[52]      'I(K,K;K+2,K+1)
      ' ; F
[53]      'I(K,K+1;K+2,K+1)
      ' ; G
[54]      'I(K,K+1;K+2,K+2)
      ' ; H
      ▽
[1]      RESULT←NEWZERO REPLACE VECTOR;ZERO;MASK;XSUB
[2]      ZERO←1E-40
[3]      MASK←(1 VECTOR)≤ZERO
[4]      XSUB←MASK/MASK*10MASK
[5]      VECTOR[XSUB]←NEWZERO
      RESULT←VECTOR
      ▽

```

Fig. 7 (Cont'd): Listings of the APL functions ABCD and REPLACE
T-1/306-3-14

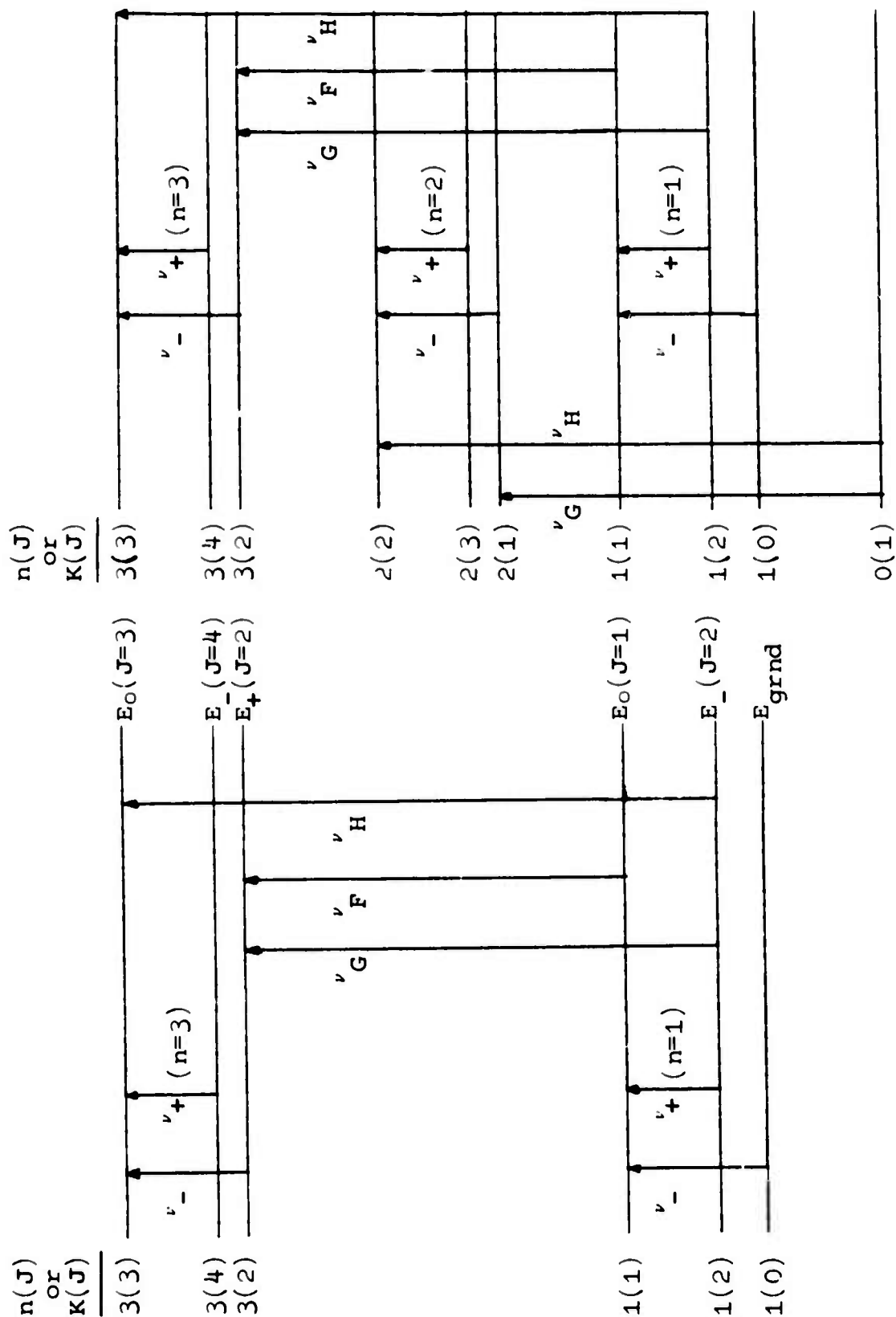


Fig. 8: Allowed magnetic dipole transitions (After Ref. 11)

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coverage of Steinbach's thesis,¹¹ all of our transition matrix elements in Appendix B agree with those of his Tables 11-13. Steinbach has also noted¹¹ the discrepancy of these results with those tabulated by Tinkham and Strandberg.¹ We have been unable to ascertain whether or not our results also agree with those of Gebbie, et al, who only give integrated line strengths in units of $10^{-8} \text{ cm}^{-2} \text{ atm}^{-1}$.⁸ In Appendix E, we list our results for integrated line strengths in these units, taken to refer to 273K, so that $1(\text{cm-atm})_{\text{STP}} = 2.686754(84) \cdot 10^{19} \text{ molecules/cm}^2$.²³ The results in Appendix E exhibit discrepancies of as much as a factor of two with the results of Gebbie, et al.,⁸ but inasmuch as no temperature is specified in Ref. 8, the precise magnitude of the discrepancies is difficult to ascertain.

Line Widths

For molecular oxygen at pressures characteristic of altitudes below 40 km, pressure-broadening predominates.²⁶ Near an isolated transition frequency, pressure-broadened molecular absorption is well-approximated by a Lorentz line shape with half-width $\alpha = \alpha_0 \cdot p$ at half-maximum points, where p is the pressure.^{23,27} (Bold-face alphas are used to distinguish them from the quantities appearing in Eqs. (1), (4), (13), and Table II.) Then the absorption at the peak of the spectral line will be given by $S_0 = S(T)/\pi\alpha$, where $S(T)$ is given by Eq. (9),^{23,27*} and will fall off away from the peak in accordance with whatever lineshape is most suited to the particular spectral region:²⁸ Van Vleck-Weisskopf in the microwave region,¹² "kinetic" in the submillimeter region,^{29,30} and Lorentz or "super-Lorentz" in the infrared and visible regions.³¹

Of the line parameters required to perform atmospheric transmission calculations,²³ the linewidths for oxygen are the least accurately characterized ones, unfortunately. The experimental values of α_0 (in MHz/torr) measured for $^{16}\text{O}^{16}\text{O}$ in the microwave region by several investigators between 1952 and 1968 (at 300K)

* $S(T)$ actually should be replaced by $S_m(T)$. (See page 17.)

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have been summarized conveniently in a review article by P. H. Krupenie.³² These experimental values, converted to $\text{cm}^{-1}/\text{atm}$ and rounded to two significant figures, have been employed in the line parameter compilations for molecular oxygen contained in this report. ($1 \text{ MHz/torr} = (760)/(29979.2458) \pm 0.02535 \text{ cm}^{-1}$ per atm.) To the degree of uncertainty (as much as 25%) inherent in the data,^{26,33} no correction has been made for a possible isotope effect in the line widths; instead, a crudely linear interpolation on K was made from Krupenie's Table 34,³² to describe the widths expected for the even-K states in $^{16}\text{O}^{18}\text{O}$ (see Fig. 8), and the tabulated values themselves³² were used for the odd-K states in all three isotopes considered.

Other than the relatively crude results in Ref. 8, no data are available in the literature concerning the widths of the submillimeter lines of molecular oxygen. If one assumes that the line widths depend on the value of K in the lower state, and one notes that "G" and "H" transitions with $K' = n$ possess the same lower states as the microwave "+" transitions with the same n (see Fig. 8), then one may safely assume that these two types of submillimeter transition possess the same line widths as the associated microwave "+" transition. Somewhat arbitrarily, the line widths for "F" transitions have been taken as the arithmetic mean of the linewidths of the "+" and "-" transitions with the same value of n.

An alternative procedure of even less accuracy would have been to use the electron-optical data³⁴⁻³⁶ to deduce the submillimeter line widths. However, unlike the K-dependence found for the microwave line widths, the J-dependence exhibited by the line widths in the visible region³⁴⁻³⁶ is unlikely to be correct for the submillimeter lines.

For lines corresponding to higher values of K than have been measured in the microwave region, a lower limit of $0.032 \text{ cm}^{-1}/\text{atm}$ has been assumed. The line widths are entered in

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lines 27-30 of AFCRLFILE (Fig. 9), lines 29-31 of AFCRL60K15 (Fig. 10), and similarly in the other "AFCRL"-format-setting programs listed (by name and short comment only) in Appendix A.

The determination of line widths near room temperature and 1 atm for molecular oxygen is complicated by the demonstrated breakdown of the independent-line approximation in the microwave region.^{26,33} The microwave line widths have been treated in the past by assuming α_0 to be pressure-dependent,^{37,38} and more recently by means of several interacting-line theories.³⁹⁻⁴² Since the microwave-line-width situation in molecular oxygen is under current active study at several institutions,⁴³ it was decided to use the Krupenie compilation³² to obtain interim (± 10 to 25%) values for the line widths, pending further results expected during the next year.*

Line Parameters in "AFCRL Format"

McClatchey, et al²³ have described their compilation of molecular spectroscopic parameters for seven infrared-active molecules which occur naturally in the terrestrial atmosphere. As of 1 April 1975,⁴⁴ all of the submillimeter lines of oxygen were absent from the AFCRL computer tape, and the microwave lines were all represented as having the line width, 0.060 cm^{-1} per atm. It was in order to supply the data on molecular oxygen which was missing (and is required as input to the RRI SLAM program⁴⁵) that the calculations described in this Research Note were undertaken. Having performed the calculations described in the preceding sections, we therefore made use of the APL output-formatting program ΔFMT (described in Ref. ⁵²46) to cast our results into a form compatible with the AFCRL format.²³ This was accomplished by means of the eight APL programs whose names begin with "AFCRL" in the defined-function list in Appendix A. Two of these (for $^{16}\text{O}^{16}\text{O}$ in the vibrational ground state) are

* Since $S(T)$ has been calculated fairly precisely in this report, measurements of peak absorption in the submillimeter region should yield line-width values which can help clarify the microwave line-width situation (because of the relationships discussed above).

```

V APCRFILE:X:NU:S:EL:W:X:JU:KU:JL:KL:TX:TEXT:CARD
  THIS PROGRAM LISTS THE FREQUENCY, LINE STRENGTH, LINEWIDTH, ENERGY
  OF LOWER STATE, QUANTUM NUMBERS OF UPPER AND LOWER STATE, LINE TYPE ID,
  DATE, ISOTOPE, AND MOLECULE, IN THE FORMAT OF THE APCR FILE PARAMETERS
  A COMPILATION. UNITS ARE: INVERSE CM, INVERSE CM PER MOLECULE PER CM SQ,
  INVERSE CM/ATM, INVERSE CM, V'', J'', K'', V'', J'', K'', (SF, SG, OR SH)
  A MONTH AND YEAR, SECOND DIGITS OF ISOTOPIC SPECIES (66 MEANS 016=016).
  A AND MOLECULE (7 = OXYGEN).
  'REFNO = ':REFNO
  'TEMP = ':TEMP
  NU+(3*OF)PO
  S+(3*OF)PO
  EL+(3*OF)PO
  X+1
  LOOP:NU[(3*X)-2]*NUF[X]
  NU[(3*X)-1]*NUG[X]
  NU[(3*X)]*NUH[X]
  S[(3*X)-2]*SF[X]
  S[(3*X)-1]*SG[X]
  S[(3*X)]*SH[X]
  EL[(3*X)-2]*ELF[X]
  EL[(3*X)-1]*ELG[X]
  EL[(3*X)]*ELH[X]
  X+X+1
  +X(OF)/LOOP
  A LINEWIDTHS BASED ON KRUPPIE COMPILATION (1972):
  A SEE PAGE 28 OF REPORT FOR DISCUSSION.
  W+0.048 0.045 0.045 0.045 0.044 0.044 0.043 0.042 0.042 0.041 0.041
  W+W,0.041 0.04 0.04 0.041 0.039 0.039 0.038 0.038 0.036 0.034 0.034
  W+W,0.037 0.036 0.036 0.036 0.035 0.035 0.035 0.035 0.035 0.032 0.032
  W+W,((-36+(3*OF))PO.032)
  A-NINPUT
  JU+JU[A(JU+(K+1),(K+1),(K+2))]
  KU+KU[A(KU+(K+2),(K+2),(K+2))]
  JL+JL[A(JL+K,(K+1),(K+1))]
  KL+KL[A(KL+K,K,K)]
  TX+((3*OF)PO('P','G','H'))
  TEXT+'F10.5,E10.3,BF5.3,F10.3, 0 0 0 I2,X1,I2,X6, 0 0 I2,X1,I2, 0 S0,A1,X5, 075 66 73'
  X+1
  LOOP2:CARD+TEXT AFMT(NU[X]:S[X]:W[X]:EL[X]:JU[X]:KU[X]:JL[X]:KL[X]:TX[X])
  +((CARD[21])*(PO(CARD[21]))PO('0'))/PRINT
  CARD[21]*((PO(CARD[21]))PO('0'))
  PRINT:0+CARD
  X+X+1
  +X(OFNU)/LOOP2
  A CALLING SEQUENCE: ABCD, ISOSTATESUM, APCRFILE.
  [45]

```

Fig. 9: Listing of APL function APCRFILE

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```

V AFCRL60K15:2,22:NU;S:EL;W:X;JU;KU;JL;KL;TX:TEXT;CARD
* THIS PROGRAM LISTS THE FREQUENCY, LINE STRENGTH, LINEWIDTH, ENERGY
* OF LOWER STATE, QUANTUM NUMBERS OF UPPER AND LOWER STATE, LINE TYPE ID,
* DATE, ISOTOPE, AND MOLECULE, IN THE FORMAT OF THE AFCL LINE PARAMETERS
* COMPILATION. UNITS ARE: INVERSE CM, INVERSE CM PER MOLECULE PER CM SQ,
* INVERSE CM/ATM, INVERSE CM, V, J, K, V, J, K, (K+ OR K-),
* MONTH AND YEAR, SECOND DIGITS OF ISOTOPIC SPECIES (66 MEANS 016=016),
* AND MOLECULE (7 = OXYGEN).
+(X=1)/CONTINUE
+0;WRONG ISOTOPE: THIS PROGRAM IS ONLY FOR 016=016.'
CONTINUE:FP+ENN-ENNPLU1;FM+ENN-ENNMIN1;GENGH2
* FP AND FM ARE THE FREQUENCIES FOR THE K+ AND K- LINES (SEE 'PRINT6002')
ELP+ENNPLU1-ENNMIN1[1];ELM+ENNMIN1-ENNMIN1[1]
* ELP AND ELM ARE THE LOWER STATE ENERGIES IN GIGAHERTZ (SEE 'PRINT6002')
LINESTRENGTH2* CALCULATES STRENGTHS, SP AND SM.
* PP AND MM MATRIX ELEMENTS FOR K+ AND K- LINES ARE COMPUTED BY ABCDLP.
NU+(2*PP)P0
S+(2*PP)P0
EL+(2*PP)P0
Z+1
LOOP:NU[(2*Z)-1]+(FP[Z])*SPEEDOFLIGHT
NU[(2*Z)]+(FM[Z])*SPEEDOFLIGHT
S[(2*Z)-1]+SP[Z]
S[(2*Z)]+SM[Z]
EL[(2*Z)-1]+(ELP[Z])*SPEEDOFLIGHT
EL[(2*Z)]+(ELM[Z])*SPEEDOFLIGHT
Z+2+1
+(ZSP)/LOOP
* LINEWIDTHS BASED ON KRUPENIE COMPILATION (1972).
W+0.045 0.05 0.044 0.047 0.042 0.044 0.041 0.044 0.04 0.043 0.039 0.041 0.038 0.039
W+W,0.034 0.038 0.036 0.038 0.035 0.037 0.035 0.035 0.032 0.038
W+W,((24+(2*PP))P0.032)
K+INPUT
KL+KU+JU+JL+JL+(K,K))
JL+((2,(PK))P((K+1),(K-1)))
TX+(2*PP)P(' ',' ')
TEXT+P10.5,E10.3,BF5.3,F10.3, 0 0 0,I2,X1,I2,X1,I2,X1,I2,X1,X5,775 66 77
SORT+ANU
Z+1
LOOP2:Z+SORT[Z]
CARD+TEXT AFMT(NU[Z];S[Z];W[Z];EL[Z];JU[Z];KU[Z];JL[Z];KL[Z];TX[Z])
+(CARD[21]+(P(CARD[21]))P('0'))/PRINT
CARD[21]+(P(CARD[21]))P(' ')
PRINT: CARD
Z+Z+1
+(ZZSPNU)/LOOP2

```

Fig. 10: Listing of APL function AFCRL60K15

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listed in Figs. 9 and 10. The format specifications in line 37 of AFCRLFILE (Fig. 9) and line 36 of AFCRL60K15 (Fig. 10) are equivalent to the FORTRAN format:

```
FREQ STRENGTH WIDTH E'' V' J' K'
(F10.5, E10.3, F5.3, F10.3, 3X, I1, 3X, I2, 1X, I2, 6X,
V'' J'' K'' ID DATE ISO MO
I1, 3X, I2, 1X, I2, 1X, A3, 5X, I2, 2X, I2, 2X, I1)
```

This format is in accordance with the one given on page 6 of Ref. 23, except that the frequency is given to five decimal places (F10.5) instead of three (F10.3).

In Appendix F, the contents of the eight files generated by AFCRLFILE, AFCRLK2, ..., AFCRL60K35 are listed. (There are two files each for the three isotopes ($^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, $^{18}\text{O}^{18}\text{O}$) in the vibrational ground state ($v = 0$) and $^{16}\text{O}^{16}\text{O}$ in the first excited vibrational state ($v = 1$); one for the submillimeter lines, the other for the microwave lines.) As indicated by the heading at the beginning of each file listing, the line parameters were generated by using Steinbach and Gordy⁷ for the molecular parameters (B_0 , B_1 , B_2 , λ_0 , λ_1 , μ_0 , μ_1) in the vibrational ground state, and Albritton, et al⁵ for those of $^{16}\text{O}^{16}\text{O}$ in the $v = 1$ state. The APL function LINESTRENGTH2 (Fig. 5) or its abbreviated form, LINESTRENGTH22 (see Appendix A), was used to compute the line strengths at 296K. (For convenience, the vibrational partition function was ignored, i. e., set equal to unity, as discussed above.) The line widths were derived from Krupenie's compilation³² in the manner indicated in the preceding section.

For clarity, at the top of each page in Appendix F, the columns have been labelled with the appropriate headings: frequency (cm^{-1}); line strength ($\text{cm}^{-1}/(\text{molecule cm}^{-2})$); line width ($\text{cm}^{-1} \text{ atm}^{-1}$); lower state energy E'' (cm^{-1}); upper state quantum numbers, V', J', and K'; lower state quantum numbers, V'', J'', and K''; shorthand line identification (K+ or K- for

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the microwave lines; SF, SG, or SH for the submillimeter lines); month and last digit of year in date of computation (75 = July 1975); isotope code (66 = $^{16}\text{O}^{16}\text{O}$, 68 = $^{16}\text{O}^{18}\text{O}$, 88 = $^{18}\text{O}^{18}\text{O}$); and molecular constituent (7 = oxygen).

The eight files listed in Appendix F were merged into a single file, ordered by frequency by means of a FORTRAN program (SRWRTMERGE) which employed the XDS Sigma 9 MERGE processor. A threshold criterion was then applied to the resulting merged file to select only the most "significant" lines: only lines whose strengths exceeded $3.7 \cdot 10^{-30} \text{ cm}^{-1}$ per molecule cm^{-2} (the "Existing Intensity Minimum at $T = 296\text{K}$ " given for O_2 in Table 3 of McClatchey, et al²³) were to be retained. (The zero frequency "lines" of zero strength in the listings for $^{16}\text{O}^{18}\text{O}$ in Appendix F--artifacts arising from the manner in which the APL programs were executed--are removed at this stage.) The resulting file, OXYGENEXIST, is listed in Appendix G. (This file was created by means of another FORTRAN program, NOSIG, which allows one to remove "cards" whose strengths lie below a user-specified level from any card-image file written in "AFCRL format".)

The file OXYGENEXIST in Appendix G contains the parameters of all "fine-structure" and "rotational" lines of the molecules, $^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}^{18}\text{O}$, which can be expected to be of significance in atmospheric absorption problems. A deck of punched cards containing the card-image records in this file was sent to AFCRL on 28 July 1975.

Summary and Comments

Calculations performed at RRI have been described which give current best estimates of the line parameters of all significant microwave and submillimeter wave absorption lines of the molecular oxygen isotopes, $^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}^{18}\text{O}$, at zero magnetic field. The transition frequency (given to the

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nearest $.00001 \text{ cm}^{-1} \pm 0.3 \text{ MHz}$) and energy of the lower state (quoted to the nearest $.001 \text{ cm}^{-1}$) have absolute accuracies on the order of $.001 \text{ cm}^{-1}$ as judged by the degree of consistency between measured³⁻⁷ and predicted values (Appendix B). These results are certainly in agreement with recent low-resolution stratospheric Fourier-transform spectroscopic measurements⁴⁶ of the submillimeter emission by the earth's atmosphere between 35 and 200 cm^{-1} . The rms deviation between our calculated frequencies and the twenty-seven observed lines of $^{16}\text{O}^{16}\text{O}$ short of 200 cm^{-1} is $.05 \text{ cm}^{-1}$, which is within the $.07 \text{ cm}^{-1}$ (unapodized) resolution of the measurements.

Integrated line strengths at 296K, accurate to within one unit in the third decimal place, have been calculated; the new results are in apparent disagreement (Appendix E) with earlier published line strengths⁸ for $^{16}\text{O}^{16}\text{O}$, by a factor of approximately two. We note that these earlier line strengths,⁸ together with the strength data on water and ozone lines from the AFCRL compilation,²³ have been used recently to deduce the temperature of the cosmic background radiation,⁴⁷ as well as to determine the water content of the stratosphere.^{48,49} A closer look at the data analyses may be warranted in both cases⁴⁶⁻⁴⁹ to determine whether the deduced results are significantly affected by the change in oxygen line strengths to the new values we report.

The least certain parameters are the line widths, for which we chose interim values, based on Ref. 32. The line widths in the microwave region are currently under intensive study⁴¹⁻⁴³ so that we should be able to improve on the line width estimates during the next year. We pointed out that direct study of the submillimeter line widths could help to clarify some of the issues attending the more complicated problem of the microwave line widths. The line widths which we give here must be viewed as uncertain to ± 10 to 25%.

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APPENDIX A

Brief Description of APL Notation and Output Formats

The intent of this Appendix is to enable the reader unfamiliar with APL to verify that the algebraic expressions given in this report have been implemented properly within the APL "functions" (programs), and to explain the APL output formats in Appendices B and E.

APL⁵⁰⁻⁵² is an interactive, time-sharing-oriented, programming language which is especially suited to working with arrays in one or more dimensions with a minimum of looping or branching. It uses a special symbol set,^{51,52} many of whose elements have intuitively clear meanings (e. g., the parenthesis pairs, (and), or the binary operators, +, -, *, etc.), but the same symbol may play different roles, depending on the context (e. g., $\square$ or ρ). The following rules are of principal importance in following the APL programs listed in this report:

1. Operations are performed from right to left, with no hierarchy between addition, multiplication, etc. In most of the programs listed, parentheses have been used liberally to make the resulting expressions look more like ordinary algebra. Examples: $\div$ means "multiply by reciprocal of everything to the right"; $-/$ means "sum the alternating series resulting from the placement of a binary minus between all elements of the array sequence beyond the slash (/)".

2. Operators can be unary or binary ($\div B$ means "take reciprocal of B"; $A \div B$ means "A divided by B" where A and B are arrays of the same "rank" (dimensions) or scalar); functions can be

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niladic (e. g., GENGHZ), monadic, or dyadic (e. g., REPLACE, or the intrinsic^{51,52} function Δ FMT).

3. Substitution is indicated by an arrow pointing left; $M \leftarrow 5$ (equivalent to FORTRAN: $M = 5$) is not the same as $M = 5$ in APL, the latter (equivalent to FORTRAN: $M.EQ.5$) having 0 or 1 ("no" or "yes") as a result. (If M is an array, the logical relations return arrays of the same dimensions, filled with zeros and ones.)

4. APL has two kinds of minus signs. Negative numbers, such as in the exponents in Appendix C or in front of the elements of VECB1 in PARAMSTEIN, are preceded by the unary, upper-case minus, $\bar{}$; negation or subtraction is indicated by the binary, ordinary-looking, minus, $-$. Example: If A is $\bar{5} \ 4 \ 0 \ \bar{3}$, the result of the operation $-A$ is: $5 \ \bar{4} \ 0 \ 3$.

5. While standard texts⁵⁰⁻⁵² should be referred to for the meanings and syntax of the special APL symbols, the following occur sufficiently often in our programs to merit discussion:

, (comma) used as a binary operator means "concatenate": $0 \ 1 \ 2, 0 \ 1$ produces the result $0 \ 1 \ 2 \ 0 \ 1$. (See lines 27-30 of AFCTRLFILE.) Used as a unary operator (as in line 34 of AFCTRL60-K15), it means "ravel", or string out as a vector. (The special symbol $\vee$ means "transpose".)

;(semi-colon) is used for separation of independent expressions, as well as (in headers--line 0) to indicate local variables defined only within the program (as opposed to global variables such as SPEEDOFLIGHT, defined "forever").

* (asterisk) denotes exponentiation: $A*B$ means A^B (binary operator); $*B$ means e^B (unary operator).

| (vertical) denotes absolute value: $|A$ means $|A|$.

⍤ (iota) is the "index" operator, with unity as the origin: $\bar{1} \times_{\bar{1}} 5$ produces the result $\bar{1} \times (1 \ 2 \ 3 \ 4 \ 5)$ or $\bar{1} \ \bar{2} \ \bar{3} \ \bar{4} \ \bar{5}$.

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ρ (rho) used monadically is the dimension operator: ρA returns an integer vector with the dimensions of A. Example: $\rho(2 \ 1 \ 5)$ returns 3. (The integer vector has one element in this case since A was a vector.) ρ (rho) used dyadically is the reshape operator: $A \rho B$ returns an array whose dimensions are given by the left (vector) argument A, and whose (initial) values are given by the right argument B. If B does not contain sufficient values, it is recycled. Example: $2 \ 5 \ \rho \ 3$ returns the 2-by-5 array, $\begin{matrix} 3 & 3 & 3 & 3 & 3 \\ 3 & 3 & 3 & 3 & 3 \end{matrix}$.

$\dagger$ and $\downarrow$ are the "take" and "drop" operators. Examples: Let A be the array 5 3 2 4 0 3. Then $3\dagger A$ yields 5 3 2; $3\downarrow A$ yields 4 0 3. See also lines 34-39 of the function ABCD (Fig. 7).

[and] (brackets) enclose line numbers in program listings and also indicate array indices. Examples: If $A \leftarrow 2 \ 3 \ 1 \ 0$, then $A[3]$ is 1; if M is a two-dimensional matrix, $M[5;]$ picks out the fifth row (all columns) of M.

6. Branching is indicated by the arrow pointing right, and the syntax is illustrated by the example: $\rightarrow(x \neq 2)/\text{NEXT}$ which is equivalent to the FORTRAN statement IF (X.NE.2.0) GO TO NEXT.

7. The APL system carries out all calculations to approximately 16 significant digits. The results are displayed rounded off to the number of digits specified by a system command,)DIGITS. Even after output display is called for, the full 16-digit-accuracy is retained in the system memory.

8. The "default" output format for the vector quantities in Appendix B is to be understood as a list, in one-to-one correspondence with the array NINPUT given at the start of each page. In Appendix E, the "take 5" operation has been applied before printing out results relating to Ref. 8, so that these arrays refer to the first five values of NINPUT. (Similar comments hold for the experimental values of ERL in Appendix B.) Note that trailing zeros are suppressed on display.

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TABLE A-1: DIRECTORY OF APL FUNCTIONS CREATED FOR THIS REPORT

<u>FUNCTION NAME</u>	<u>COMMENT</u>	<u>PAGE</u> ::
ABCD	USED TO CALCULATE TRANSITION MATRIX ELEMENTS	24-25
ABCDLP	VERSION OF ABCD USED FOR LINE PRINTER OUTPUT	N/A
ABCDUPPER	VERSION OF ABCD FOR V = 1 STATES OF O16=O16	N/A
AFCRLFILE	LISTS LINE PARAMETERS OF O16=O16 FOR V = 0	30
AFCRLK2	VERSION OF AFCRLFILE FOR O16=O18 (V = 0)	N/A
AFCRLK3	VERSION OF AFCRLFILE FOR O18=O18 (V = 0)	N/A
AFCRL5K15UPPER	VERSION OF AFCRLFILE FOR O16=O16 FOR V = 1	N/A
AFCRL60K15UPPER	LISTS '60 GHZ' LINES OF O16=O16 FOR V = 1	N/A
AFCRL60K15	LISTS '60 GHZ' LINES OF O16=O16 FOR V = 0	31
AFCRL60K25	VERSION OF AFCRL60K15 FOR O16=O18 (V = 0)	N/A
AFCRL60K35	VERSION OF AFCRL60K15 FOR O18=O18 (V = 0)	N/A
COMPARAMAN	COMPUTES RMS DIFFERENCES BETWEEN PREDICTED AND OBSERVED LASER 'RAMAN' LINES	N/A
FREQLIST	PRINTS OUTPUT OF PARAMSTEINLP, SUBMMO2, PRINT6002, AND COMPARAMAN (SEE APPENDIX B)	N/A
GBBSTRENGTH	PRINTS OUTPUT OF LINESTRENGTH22 AND COMPARES WITH RESULTS OF REF. 8 (SEE APPENDIX E)	N/A
GENGHZ	GENERATES ENERGY LEVELS IN GIGAHERTZ	12
GENINVCN	CONVERTS GENGHZ OUTPUT TO INV CM AND GENERATES MICROWAVE TRANSITION FREQUENCIES (ALSO INV CM)	13
ISOSTATESUM	COMPUTES ROTATIONAL PARTITION FUNCTION	19
ISOSTATESUMLP	VERSION OF ISOSTATESUM FOR LINE PRINTER OUTPUT	N/A
LINESTRENGTHROT	VERSION OF LINESTRENGTH2 FOR O16=O16, V = 1	N/A
LINESTRENGTH2	COMPUTES LINE STRENGTHS FOR ALL OXYGEN LINES	18
LINESTRENGTH22	COMPUTES LINE STRENGTHS OF SUBMILLIMETER LINES	N/A
PARAMETERS	GIVES B0, B1, B2, LAM0, LAM1, MU0, MU1 ACCORDING TO ANY ONE OF REFS. 1 THROUGH 6 FOR O16=O16	73
PARAMETERSLP	VERSION OF PARAMETERS FOR LINE PRINTER OUTPUT	N/A
PARAMSTEIN	GIVES B0, B1, B2, LAM0, LAM1, MU0, MU1 ACCORDING TO REF. 7 FOR ANY OF THREE ISOTOPES; SETS NINPOT AND TEMPERATURE	8
PARAMSTEINLP	VERSION OF PARAMSTEIN FOR LINE PRINTER OUTPUT	N/A
PARAMSTEINUPPER	VERSION OF PARAMETERS FOR O16=O16, V = 1 (REF. 5)	74
PRINTGHZ	PRINTS OUTPUT OF GENGHZ	N/A
PRINTINVCN	PRINTS OUTPUT OF GENINVCN	N/A
PRINTSTATSUM	PRINTS STATE SUM VS. TEMPERATURE (SEE APPENDIX D)	N/A
PRINTSTRENGTH2	PRINTS OUTPUT OF LINESTRENGTH2	N/A
PRINTSUBMMO2	PRINTS OUTPUT OF SUBMMO2	N/A
PRINT6002	CALCULATES MICROWAVE TRANSITIONS, LOWER STATE ENERGIES, AND LASER 'RAMAN' LINES (IN GHZ), AND PRINTS RESULTS (SEE APPENDIX B)	N/A
REPLACE	BINARY FUNCTION WHICH REPLACES 'ZERO' VALUES	25
SUBMMO2	CALCULATES SUBMILLIMETER TRANSITION FREQUENCIES AND LOWER STATE ENERGIES (IN INVERSE CM)	15

:: LISTINGS OF APL FUNCTIONS MENTIONED HERE BUT NOT APPEARING EXPLICITLY (MARKED N/A IN THIS COLUMN) ARE AVAILABLE FROM THE AUTHOR UPON REQUEST.

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APPENDIX B

Molecular "Rotational" Parameters, Millimeter and Submillimeter Wave Transition Matrices, Transition Frequencies, and Lower State Energies in the Ground ($^3\Sigma_g^-, v = 0$) State of $^{16}O^{16}O$, $^{16}O^{18}O$, and $^{18}O^{18}O$, and in the First Excited Vibrational State ($v = 1$) of $^{16}O_2$, According to References 1 through 7

For each of the ten sets of parameters studied, there are three pages of computer printout. The first of the three pages gives the rotational parameters, B_0 , B_1 , B_2 , LAM_0 , LAM_1 , MU_0 , and MU_1 in GHz and in cm^{-1} , the Reference number, isotope code, the array of K-values, and the corresponding arrays of normalized transition matrices. The second page repeats the Reference number and array of K-values (NINPUT), followed by the submillimeter frequencies (cm^{-1} and GHz) and lower state energies (cm^{-1}) with respect to the ground state. The third page repeats the Reference number and NINPUT, followed by the microwave transition frequencies and lower state energies with respect to the ground state (GHz) and the predicted and observed "laser-magnetic-resonance" lines⁶ and their rms difference in MHz and cm^{-1} .

The sequence of the ten sets of parameters is as follows: Ground vibrational state of $^{16}O^{16}O$ ($v' = v'' = 0$), in order of Reference number (1 through 7); Ground states of $^{16}O^{18}O$, $^{18}O^{18}O$ (Ref. 7); first excited vibrational state ($v' = v'' = 1$) of $^{16}O^{16}O$ (Ref. 5). (In the last case, $\Delta G_{1/2}$ is not included in the lower state energy, as discussed in the text on p. 14.)

THE PARAMETERS ACCORDING TO TINKHAM AND STRANDBERG
(REF. 1) ARE AS FOLLOWS:

H0 = 3.1029 GMZ = 1.43775798 INVERSE CM;
H1 = -0.00117199 GMZ = -4.908392325E-6 INVERSE CM;
H2 = 0 GMZ = 0 INVERSE CM;

LAM0 = 59.50157 GMZ = 1.984758736 INVERSE CM;
LAM1 = 5.678E-5 GMZ = 1.893976933E-6 INVERSE CM;

U0 = -0.25267 GMZ = -0.008428163993 INVERSE CM;
U1 = 0 GMZ = 0 INVERSE CM.

TEMP = 296 REFNO = 1 ISOTOPE = 66
K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

IK,K+1,K,K+1
2.45198758 6.71035733 10.80289208 14.85056609 18.87965109 22.89924847 26.91335004 30.9239832 34.93228715
38.93895134 42.94441752 46.94898182 50.95285018 54.95617028 58.95908076 62.96157333 66.96380063 70.9657815
74.96755456 78.96915074 82.97059515 86.97190834 90.97310731 94.97420626 98.97521711 102.97619 106.9770134
IK,K=1,K,K+1
2 6.538633547 10.73656757 14.81539485 18.8578617 22.8842557 26.90261358 30.91584825 34.92591044 38.93381849
42.94019697 46.94545021 50.94985158 54.953525 58.95681103 62.95960926 66.9620643 70.96423548 74.96616519
78.96790223 82.96946419 86.97087909 90.97216665 94.97333324 98.9742251 102.975416 106.9763334

IK,K,K+2,K+1
0.0401242004 0.0396452658 0.03044125341 0.02443391254 0.02034890746 0.01741820113 0.01522139115 0.0135168003
0.01215729513 0.01104865784 0.01012793027 0.00935151092 0.008688277233 0.00811543384 0.00761590952 0.0071767223
0.006787600558 0.006440718451 0.00612965977 0.005849260756 0.00559532901 0.005364349627 0.005153554908 0.004960402489
0.004782885384 0.004619262115 0.004488041875

IK,K+1,K+2,K+1
0.3924195254 0.2128270418 0.145747365 0.111901612 0.09054753909 0.07607063849 0.0656102092 0.0576994803
0.5150943269 0.04653515144 0.04245180768 0.03904088056 0.03614994067 0.03364941462 0.03151851024 0.02963634836
0.02797618267 0.02650152421 0.02518347406 0.02399884768 0.02292882929 0.02195798943 0.02107355627 0.02026486734
0.01952295165 0.01884020734 0.01821013041

IK,K+1,K+2,K+2
0.1280331201 0.06343242652 0.04174800468 0.03102719053 0.02446534238 0.02046334119 0.01748508522 0.01526603328
0.01354992646 0.01218398358 0.01107152625 0.01014842229 0.009370467889 0.008706212604 0.008132673586 0.00763266021
0.007193092578 0.006803785977 0.006456739423 0.006145564772 0.005865098134 0.005611123826 0.005380165124
0.005169329559 0.004976191276 0.00479870071 0.004635114457

REFNO = 1
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O16=O14 ARE AS
 FOLLOWS (IN UNITS OF INVERSE CM):

NUF:	12.2925742	23.8643608	35.3972642	46.9139559	58.4183923	69.9104627	81.3898344	92.854497	104.303035	115.733727
	127.144794	138.534423	149.900778	161.242201	172.55624	183.841645	195.096353	206.318453	217.506048	228.657382
	239.770456	250.84343	261.874424	272.861555	283.802943	294.696705	305.540958			
NUG:	14.1693627	25.8139385	37.3850231	48.9298923	60.4581758	71.9721127	83.4716627	94.9558498	106.423447	117.872778
	129.302209	140.709998	152.094358	163.453477	174.785522	186.088649	197.361002	208.600721	219.80594	230.97479
	242.109397	253.195887	264.244383	275.249008	286.207883	297.119128	307.980862			
NUM:	16.2534938	27.8255344	39.3585222	50.8753555	62.3799059	73.8723506	85.3517268	96.8166242	108.265427	119.696415
	131.107808	142.497792	153.864534	165.206182	176.52088	187.806762	199.061958	210.284595	221.472799	232.624692
	243.728394	254.812027	265.84371	276.831561	287.773699	298.668241	309.513305			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
 CM) ARE AS FOLLOWS:

ELF:	3.96109488	18.3380022	44.2139579	81.5847231	130.444172	190.784295	262.595195	345.865094	440.580325	546.72534
	664.282703	793.233095	933.555313	1084.22627	1248.22098	1422.5126	1608.07238	1804.86969	2012.87201	2232.04496
	2462.35224	2703.7557	2956.21527	3219.68902	3494.13313	3779.50189	4075.7477			
ELG:	2.08430838	16.3884244	42.226201	79.5688167	128.404389	188.722845	260.513367	343.763701	438.459913	544.586288
	662.125288	791.05782	931.361732	1083.0148	1248.99172	1420.26581	1605.80773	1802.58742	2010.57216	2229.72755
	2460.0173	2701.40384	2953.84831	3217.30157	3491.78819	3777.07946	4073.3078			
ELM:	2.08430838	16.3884244	42.226201	79.5688167	128.404389	188.722845	260.513367	343.763701	438.459913	544.586288
	662.125288	791.05782	931.361732	1083.0148	1248.99172	1420.26581	1605.80773	1802.58742	2010.57216	2229.72755
	2460.0173	2701.40384	2953.84831	3217.30157	3491.78819	3777.07946	4073.3078			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	364.582103	715.435538	1061.18334	1406.44491	1751.33934	2095.84894	2440.00585	2783.70779	3126.92632	3469.60988
		3811.70503	4153.19751	4493.91226	4833.91384	5173.10684	5511.43446	5848.84153	6185.27161	6520.66849	6854.97587
		7188.13745	7820.09486	8500.79772	9180.18364	9858.19819	10534.78495	11207.88747			
NUG	(GMZ)	424.786807	773.882408	1120.7748	1466.88127	1812.49051	2157.66966	2502.41749	2846.70596	3190.49469	3533.737
		3876.38272	4218.37941	4559.67415	4900.21197	5239.53814	5578.79734	5916.73394	6253.6423	6589.61632	6924.445
		7590.62173	7921.84732	8251.75768	8580.29648	8907.40737	9233.03396				
NUM	(GMZ)	487.273481	834.188506	1179.93881	1525.20479	1870.10253	2214.63736	2558.7804	2902.48538	3245.71585	3588.40424
		3930.51319	4271.97634	4612.74267	4952.75675	5291.96285	5630.30507	5967.72736	6304.17357	6639.58748	6973.41241
		7307.09323	7639.0724	7969.79393	8299.20143	8627.23846	8953.84862	9278.97544			

REFNO = 1

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
016=016 ARE AS FOLLOWS:

FM: 56.2647039 58.444687 59.5914529 60.4353529 61.151168 61.8007158 62.4116423 62.9981712 63.5683689 64.1271513
64.6776895 65.2221038 65.7618944 66.2981279 66.8315937 67.3628869 67.8924649 68.4206844 68.9478283 69.4741234
69.999754 70.5248711 71.0496 71.5740449 72.098294 72.6224218 73.1464918
FM: 118.750697 62.4866746 60.3060983 59.1640137 58.3235206 57.6120207 56.9674967 56.3629024 55.7834142 55.2211658
54.671241 54.130473 53.5967293 53.0685218 52.54478 52.0247143 51.5077295 50.9933686 50.4812746 49.9711648
49.4623121 48.9560325 48.4506748 47.9466139 47.4437453 46.9419811 46.4412467

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4859932 491.312605 1265.90966 2385.41311 3849.46673 5657.76855 7809.99426 10305.7765 13144.6975 16326.2862
19850.0167 23715.1078 27921.5223 32467.9668 37333.892 42578.492 48140.9046 54040.2112 60275.437 66845.5503
73749.4634 80986.0318 88554.0546 96452.2744 104679.378 113233.994 122114.696
ELM: 0 487.2728 1265.19501 2386.68445 3852.29438 5661.95725 7815.43821 10312.4118 13152.4823 16335.1922 19860.0232
23726.3995 27933.6875 32481.1964 37368.1788 42593.8301 48157.2893 54057.6386 60273.9035 66865.0533 73770.0003
81007.6006 88576.6835 96475.9019 104704.032 113259.674 122141.401

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'=J'-N+2 (IN GHZ) ARE:

ERL: 431.008778 775.741636 1120.34736 1464.76943 1808.95136 2152.83644 2496.36875 2839.4912 3182.14748 3524.28109
3865.83551 4206.75424 4546.98078 4886.45562 5225.13126 5562.94219 5899.8349 6235.75289 6570.63965 6904.43868
7237.09348 7568.54753 7898.74433 8227.62738 8556.14017 8881.22619 9205.82895

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697 775.6978 1120.3 1464.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.81
THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 1 AND THOSE OBSERVED IS:
0.0779761657 GHZ = 77.9761657 MHZ = 0.00260100491 INVERSE CM.

THE PARAMETERS ACCORDING TO WILFITT AND BARRETT
(REF. 2) ARE AS FOLLOWS:

B0 = 3.100589 GMZ = 1.437680897 INVERSE CM
B1 = 3.00014 GMZ = 4.649897333E-6 INVERSE CM
B2 = 0 GMZ = 0 INVERSE CM

LAM0 = 59.501346 GMZ = 1.98475126 INVERSE CM
LAM1 = 5.845E-5 GMZ = 1.949682136E-6 INVERSE CM

W0 = 0.2525917 GMZ = 0.00425552187 INVERSE CM
W1 = 2.455E-7 GMZ = 8.188998537E-9 INVERSE CM

TEMP = 296 REFNO = 2 ISOTOPE = 66

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)

2.451982934 6.710351231 10.8028898 14.8505447 18.87965041 22.89924837 26.91335046 30.92398409 34.93228447
38.93895307 42.9441965 46.9484432 50.9528305 54.95617351 58.95905434 62.9615727 66.96380492 70.96574614
74.96755954 78.96915608 82.9706063 86.97191437 90.9731137 94.97421301 98.97522421 102.9761574 106.9770213

I(K,K+1)K(K)

2 6.538621158 10.73656197 14.81531172 18.85785994 22.8844274 26.90261347 30.91564873 34.92591144 38.93381997
42.94019888 46.9454253 50.9498429 54.9535959 58.95681449 62.95961309 66.96206849 70.96424002 74.96617409
78.96790749 82.9694698 86.97088505 90.97217297 94.97334991 98.97442953 102.9754234 106.9763411

I(K,K+2)K(K+1)

0.04801706559 0.03964876905 0.03044353464 0.0244435294 0.02034958707 0.01741829286 0.01522098825 0.01351591142
0.01215597389 0.01104692815 0.01012580951 0.009349011909 0.00868540946 0.008112204379 0.007612323816 0.007172733099
0.006783310856 0.006436079613 0.00612466751 0.005843924757 0.005589643656 0.005352353049 0.005147166545 0.004953659527
0.004775785192 0.00461180167 0.004460217782

I(K,K+1)K(K+2)K(K+1)

0.3924367513 0.212845733 0.1465856896 0.1119079375 0.09055055993 0.07607103898 0.06506819909 0.05749567543
0.05150383665 0.04452786833 0.0424429205 0.0390304972 0.03613801055 0.03365601795 0.03150367101 0.02962005342
0.02795850377 0.02648243859 0.02516298531 0.0239769563 0.02290553312 0.021933328396 0.0210474349 0.02023732157
0.01949397123 0.0188097804 0.01817826352

I(K,K+1)K(K+2)K(K+2)

0.124055082 0.06343803048 0.04175113322 0.0310289473 0.02446616615 0.02046244895 0.01748459943 0.01526502937
0.01354845387 0.01218207615 0.01106920791 0.01014571031 0.00936737494 0.008702747993 0.00812684412 0.00762447603
0.007188247608 0.006798885645 0.006451486325 0.006139958468 0.0058559138671 0.005604812225 0.005373495854 0.005162302259
0.0049688804121 0.004790950458 0.004626997795

REFNO = 2
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF 016-016 ARE AS
 FOLLOWS (IN UNITS OF INVERSE CM):

NUG:	12-2918502	23-8631552	35-3957897	46-9125382	58-4173647	69-9105379	81-3911871	92-8579938	104-309434	115-74388
	127-159643	138-555002	149-928213	161-27752	172-601156	183-897348	195-124319	206-400287	217-603469	228-77208
	239-904333	250-398441	262-092613	273-065063	284-033998	294-957629	305-834166			
NUG:	14-1686401	25-8127231	37-3835307	48-9284254	60-457128	71-9719696	83-4730017	94-9593808	106-429852	117-882952
	129-3117099	140-730642	152-121889	163-485118	174-830589	186-144551	197-42924	208-682889	219-903723	231-089965
	242-239836	253-351553	264-423331	275-453385	286-439929	297-381175	308-275335			
NUG:	16-2529581	27-8243171	39-3870365	50-8739008	62-3788739	73-8722244	85-3530821	96-8201281	108-271839	119-706585
	131-12268	142-518401	153-892006	165-241733	176-565829	187-862508	199-129995	210-366511	221-570272	232-739493
	243-872386	254-967165	266-02204	277-038422	288-004922	298-929348	309-80671			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
 CM) ARE AS FOLLOWS:

ELF:	3-96108476	18-337253	44-2120023	81-5812977	120-439311	150-778422	262-589215	345-860482	440-579223	546-730644
	644-298156	793-26338	933-606141	1085-30447	1248-33461	1422-67101	1608-28631	1805-15139	2013-2353	2232-50532
	2462-92692	2704-46381	2957-07786	3220-72918	3495-37608	3780-97507	4077-48088			
ELG:	2-08429488	14-3876851	42-2242612	79-5454105	128-399548	188-71699	260-5074	343-759095	438-458805	544-591571
	791-087739	931-412465	1083-09287	1246-10518	1420-42381	1606-02139	1802-86879	2010-93504	2230-18743	2460-59142
	2702-1107	2954-70714	3218-34086	3492-97015	3778-55153	4075-03971				
ELM:	2-08429488	16-3876851	42-2242612	79-5454105	128-399548	188-71699	260-5074	343-759095	438-458805	544-591571
	791-087739	931-412465	1083-09287	1246-10518	1420-42381	1606-02139	1802-86879	2010-93504	2230-18743	2460-59142
	2702-1107	2954-70714	3218-34086	3492-97015	3778-55153	4075-03971				

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUG	(GMZ)	368-5044	715-399396	1061-13908	1406-40252	1751-30853	2095-8652	2440-0444	2783-81262	3127-11817	3469-91422
		3812-15018	4153-77445	4494-73475	4834-97842	5174-45249	5513-10381	5850-87909	6187-72494	6523-58789	6858-41442
NUG	(GMZ)	7192-15097	7824-74394	7886-13971	8186-28463	8818-12504	8842-60727	9168-67764			
		424-765145	773-84597	1120-73006	1466-83729	1812-4591	2197-66337	2502-45744	2844-81062	3190-68671	3534-042
		3876-82909	4218-99851	4560-49949	4901-28044	5241-28921	5580-47324	5918-77971	6256-15561	6592-54776	6927-90287
NUG	(GMZ)	7262-16759	7551-28847	7927-21203	8287-88474	8687-25304	8919-26335	9241-86205			
		487-251427	834-152043	1179-89427	1525-16118	1870-07159	2214-63358	2558-82103	2902-59442	3245-90806	3588-71313
		3930-95905	4272-59418	4613-56629	4953-82268	5293-3104	5631-97629	5969-76708	6306-62335	6642-50965	6977-35446
		7311-11021	7643-72331	7975-14013	8305-30703	8634-17034	8961-4764	9287-77152			

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REFNO = 2
NINPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GMZ) OF

O16=016 ARE AS FOLLOWS:

FP: 56.264745 58.4465748 59.5909771 60.4347779 61.1505671 61.800167 62.4112322 62.9979965 63.5685371 64.1277813
64.6789074 65.2240593 65.7547369 66.3020223 66.8367167 67.369427 67.9008221 68.4306706 68.959867 69.48845
70.0166156 70.5445267 71.0723201 71.600112 72.1280021 72.6560769 73.1844116
CM: 118.750334 62.4862826 60.3060722 59.1642148 58.3238842 57.6124905 56.9682115 56.3633926 55.7838 55.2213565
54.6711348 54.1299865 53.6956778 53.0667988 52.5422374 52.0211923 51.5030568 50.9873618 50.4737388 49.9618933
49.4515865 48.9426225 48.4348385 47.9280375 47.4222834 46.9172963 46.4130501

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4855886 491.250441 1265.85151 2385.311 3849.32161 5657.59303 7809.81538 10305.6384 13144.6643 16326.4446
19850.4788 23716.2138 27923.0432 32470.3075 37357.2935 42583.2344 48147.3101 54048.6463 60286.316 66859.3372
73766.675 81007.2407 88579.8917 96483.4317 104716.611 113278.125 122166.817
ELM: 0 487.250733 1265.13641 2386.58156 3852.14829 5661.78071 7815.2584 10312.273 13152.449 16335.351 19860.4866
23727.3079 27935.2123 32483.5427 37371.5879 42598.5827 48163.7077 54066.0898 60304.8021 66878.8638 73787.2401
81028.8426 88602.5292 96507.1037 104741.316 113303.864 122193.388

THE PREDICTED LMR AND RAMAN LINES CONNECTING

STATES N=J WITH STATES N'-J'+2 (IN GMZ) ARE:

ERL: 430.986682 775.705448 1120.30389 1444.7264 1808.92102 2152.83341 2496.4098 2839.59642 3182.33953 3524.58535
3866.28014 4207.37012 4547.80185 4887.52066 5226.47368 5564.60687 5901.86645 6238.19868 6573.54978 6907.86601
7241.0936 7573.17878 7904.06781 8233.70691 8562.04234 8889.02032 9214.58711

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697 775.6975 1120.3 1444.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.81
THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 2 AND THOSE OBSERVED IS:
0.21373325 GMZ = 213.373325 MHZ = 0.007117368 INVERSE CM.

THE PARAMETERS ACCORDING TO WELCH AND MIZUSHIMA
(REF. 3) ARE AS FOLLOWS:

S0 = 3.100518 GMZ = 1.37678529 INVERSE CM
H1 = 0.00149629 GMZ = 4.83541858E-6 INVERSE CM
S2 = 1.07E-10 GMZ = 5.236956295E-12 INVERSE CM
LA0 = 5.7501342 GMZ = 1.984751131 INVERSE CM
LA1 = 5.847E-5 GMZ = 1.950349265E-6 INVERSE CM
MU0 = 0.2525865 GMZ = -0.00842537873 INVERSE CM
MU1 = 2.464E-7 GMZ = -8.219019306E-9 INVERSE CM

TEMP = 296 REFNO = 3 ISOTOPE = 46

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

IK,K=1JK,K1

2.5192623 6.710350719 10.8028891 14.8505638 18.87964931 22.89924706 26.91334893 30.92398234 34.93228651
38.93895085 42.94441724 46.9589817 50.97310849 54.98617043 58.99905104 62.96157373 66.96380116 70.96578214 74.9675553
78.9691516 82.97059611 86.97190941 90.97310849 94.97420754 98.9752185 102.9761515 106.977015

IK,K=1JK,K1

2 6.538620329 10.73656115 14.81539071 18.8578588 22.8844234 26.90261193 30.91584698 34.92590947 38.93381778
42.94019647 46.94544991 50.94985144 54.95359251 58.95681119 62.95960956 66.96206473 70.96423603 74.96616986
78.96790302 82.96946509 86.9708801 90.97216777 94.97334447 98.97442384 102.9754174 106.9763349

IK,K=1JK,K2,K+1

0.04801737665 0.03964928145 0.0304423627 0.02443619459 0.02035069317 0.01741960881 0.01522249717 0.01351765574
0.0121579357 0.01104910934 0.01012821187 0.009351637219 0.008688259511 0.008115281009 0.007615628933 0.007176268695
0.006787079017 0.006440082532 0.006128907591 0.005848404223 0.005594365158 0.005363319865 0.00515238029 0.004959123756
0.004781503006 0.004617776319 0.00446452672

IK,K=1JK,K2,K+1

0.3924592439 0.2128484674 0.1465890585 0.1119120552 0.0903554765 0.07607678176 0.0656178556 0.0577031181
0.05151214579 0.04653705253 0.04245298777 0.03904140773 0.03614986694 0.03366878043 0.0315173475 0.02963468214
0.02797403328 0.026449890784 0.0251804037 0.02399533368 0.02292487983 0.02195361086 0.02106875338 0.02025964358
0.01951730928 0.01883414762 0.01820367366

IK,K=1JK,K2,K+1

0.1280463377 0.06343885032 0.04175209546 0.03103009091 0.02466750688 0.02046499496 0.01748435572 0.01526449943
0.01355064041 0.01218448147 0.01107183409 0.01014855935 0.00937044876 0.00870604893 0.008132373499 0.007632238846
0.00719254088 0.006803114211 0.006455552556 0.00614466485 0.005864087812 0.005610004861 0.005378938856 0.005167996967
0.004974753028 0.004797157198 0.004633465825

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REFNO = J
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O16=O16 ARE AS FOLLOWS (IN UNITS OF INVERSE CM)

NUF:	12.2918039	23.8629875	35.3953573	46.9116331	58.4157134	69.9078008	81.3869549	92.8517942	104.300718	115.732024
	127.143957	138.534712	149.902465	161.245378	172.561598	183.849261	195.104497	206.331426	217.522165	228.676821
	239.793497	250.870291	261.905292	272.896585	283.842248	294.740355	305.58897			
NUB:	14.1685942	25.8125556	37.3830964	48.9275203	60.4554768	71.9692325	83.4687716	94.9531812	106.421136	117.871099
	129.301414	140.710352	152.096142	163.456977	174.791032	186.094465	197.371419	208.61403	219.822421	230.994709
	242.129004	253.223407	264.276014	275.284913	286.248185	297.163907	308.030146			
NUM:	16.2529117	27.8241494	39.3564041	50.8729957	62.3772226	73.8694876	85.3488521	96.8139247	108.263103	119.694732
	131.106995	142.498112	153.866259	165.209537	176.526272	187.814422	199.072174	210.297652	221.488969	232.644235
	243.761552	254.839017	265.874721	276.866747	287.813175	298.712077	309.561517			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE CM) ARE AS FOLLOWS:

ELF:	3.56108467	18.3372061	44.2117874	81.5806504	130.437759	190.775218	262.583274	345.850311	440.562853	546.709557
	664.261217	793.210755	933.533226	1085.20581	1248.20381	1422.50065	1608.09786	1804.87512	2012.89016	2232.07888
	2462.40522	2703.83127	2956.31717	3219.82117	3494.29959	3779.70683	4075.99535			
ELB:	2.08429436	16.387638	42.2240463	79.5647631	128.397995	188.713786	260.501459	343.748924	438.442435	544.566485
	662.10376	791.035114	931.33955	1082.99421	1245.97437	1420.25344	1608.80294	1802.59251	2010.58991	2229.74099
	2460.06972	2701.47816	2953.94645	3217.43284	3491.89365	3777.28328	4073.55418			
ELM:	2.08429436	16.387638	42.2240463	79.5647631	128.397995	188.713786	260.501459	343.748924	438.442435	544.566485
	662.10376	791.035114	931.33955	1082.99421	1245.97437	1420.25344	1608.80294	1802.59251	2010.58991	2229.74099
	2460.06972	2701.47816	2953.94645	3217.43284	3491.89365	3777.28328	4073.55418			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	368.49901	718.394369	1061.12612	1408.37538	1751.25903	2095.78314	2439.91359	2783.62676	3126.85686	3469.55887
		3811.67995	4153.16617	4493.96285	4834.01484	5173.26656	5511.66219	5849.14562	6185.66054	6521.15044	6855.55862
		7188.8282	7520.90211	7851.72312	8181.23379	8509.37683	8836.09354	9161.32683			
NUB	(GMZ)	424.763768	773.840949	1120.7171	1466.81016	1812.4096	2157.58331	2502.3302	2846.62476	3190.4254	3533.68664
		3876.35887	4218.39024	4559.72761	4900.31689	5240.10331	5579.03166	5917.0463	6254.09128	6590.11038	6925.5716
		7258.84491	7591.44675	7922.79557	8252.83406	8581.50471	8908.74982	9234.51146			
NUM	(GMZ)	487.250035	834.147014	1179.88131	1525.13404	1870.02209	2214.55153	2558.69422	2902.40856	3245.64676	3588.3578
		3930.48883	4271.98592	4612.79441	4952.85912	5292.1245	5630.53471	5968.03364	6304.565	6640.07225	6974.49471
		7307.7875	7639.88154	7970.72361	8300.25627	8628.42192	8955.16277	9280.42081			

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REFNO: J

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GMZ) OF
J10016 ARE AS FOLLOWS:

FP: 56.2647579 58.44658 59.5909792 60.4347785 61.1505671 61.8001671 62.4112332 62.9979983 63.5685416 64.1277886
64.6789184 65.2240747 65.7647576 66.3020493 66.8367509 67.3694694 67.9006738 68.4307328 68.9559441 69.486537
70.0167169 70.5446437 71.0724542 71.6002647 72.1281752 72.6562718 73.1846301
FM: 118.750331 62.4862473 60.306065 59.1642114 58.3238834 57.6124916 56.9682142 56.3633964 55.7838046 55.2213614
54.6711396 54.1299608 53.595681 53.0688003 52.5422365 52.0211885 51.5030491 50.9873496 50.4737211 49.9618692
49.451555 48.9425826 48.4347891 47.9280374 47.4222114 46.9172111 46.4129503

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.485573 491.289028 1265.84506 2385.29159 3849.27507 5657.49699 7809.63728 10305.3335 13144.1735 16325.6925
19849.3714 23714.6361 27920.8573 32473.3497 37353.372 42578.1271 48140.7611 54040.364 60275.9691 66846.5528
73751.0348 80988.2776 88557.0867 96456.2101 104684.338 113240.104 122122.082
ELM: 0 487.249341 1265.12998 2386.56216 3852.10175 5661.68466 7815.0803 10311.9681 13151.9583 16334.5989 19859.3792
23725.7302 27933.0264 32480.5849 37367.6665 42593.4753 48157.1587 54057.8074 60294.4553 66856.0794 73771.5999
81009.8797 88579.7244 96479.8823 104709.044 113265.843 122148.854

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'=J'+N+2 (IN GMZ) ARE:

ERL: 430.985277 775.700434 1120.29033 1464.69926 1808.87152 2152.78136 2496.28298 2839.41057 3182.07822 3524.23001
3865.80991 4206.76185 4547.02945 4886.55707 5225.28775 5563.16524 5900.13297 6236.13426 6571.11231 6905.01018
7237.77078 7569.3369 7899.65115 8228.456 8556.29375 8882.50649 9207.23618

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
OBSERVED EXPERIMENTALLY ARE (IN GIGAHERTZ):

430.984697 775.6975 1120.3 1464.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.01
THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 3 AND THOSE OBSERVED IS:
0.0242882435 GMZ = 242882435 MHZ = 0.000810168597 INVERSE CM.

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THE PARAMETERS ACCORDING TO EVENSEN AND MIZUSHIMA
(REF. 4) ARE AS FOLLOWS:

H0 = -3.10518 GMZ = 1.437678529 INVERSE CMJ
 R1 = -0.0031496 GMZ = -4.835345124E-6 INVERSE CMJ
 R2 = -1.7E-10 GMZ = -5.670589618E-12 INVERSE CMJ
 LA0 = 59.501342 GMZ = 1.984751131 INVERSE CMJ
 LA1 = 5.847E-5 GMZ = 1.990349265E-6 INVERSE CMJ
 MU0 = -0.2525865 GMZ = -0.008425378733 INVERSE CMJ
 MU1 = -2.464E-7 GMZ = -8.219019306E-9 INVERSE CMJ

TEMP = 296 REFNO = 4 ISOTOPE = 66

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)

2.451982623 6.710350719 10.8028891 14.8505638 18.87964931 22.89924706 26.91334893 30.92398235 34.93222651
 38.93895089 42.94441724 46.9512317 50.95828502 54.96617044 58.97305104 62.97952185 66.9860116 70.99378214
 74.99675531 78.9991516 82.97059611 86.97190941 90.97310849 94.97420755 98.9752185 102.9761515 106.977015

I(K,K+1)K(K)

2 6.538620329 10.73656115 14.81539076 18.857858 22.884234 26.90261193 30.91584698 34.92590947 38.93381774
 42.94019647 46.9454991 50.9485144 54.9535252 58.9568119 62.9596056 66.96206473 70.96423603 74.96616986
 78.96790302 82.96946509 86.9708801 90.97216778 94.97334447 98.97442384 102.9754174 106.9763349

I(K,K+2)K(K+1)

0.04801737656 0.03964928123 0.0304423592 0.02443613611 0.02035069257 0.01741960807 0.0152224963 0.01351765475
 0.01215793458 0.01104910808 0.01012821049 0.009351635705 0.00868257864 0.008115279229 0.00761527019 0.00717626664
 0.00678707683 0.006440080208 0.006128905127 0.005848401619 0.005594362411 0.005363316976 0.005152377255 0.004959120575
 0.004781499676 0.004617772839 0.00446649039

I(K,K+1)K(K+2)K(K+1)

0.3924592432 0.212848462 0.145890568 0.111912053 0.0905554738 0.07607677856 0.06561478184 0.05770311387
 0.05151214104 0.04653704725 0.04245298197 0.03904140141 0.03614986009 0.03366877304 0.03151733957 0.02963467367
 0.02797402427 0.02649889828 0.0251803358 0.023995323 0.02292486452 0.02195359403 0.02106874097 0.02025963058
 0.01951729569 0.01883413342 0.01820365885

I(K,K+1)K(K+2)K(K+2)

0.1280463375 0.06343884996 0.04175209498 0.0310300903 0.02466750614 0.0204649941 0.0174835473 0.01526659231
 0.01355063916 0.01218448004 0.01107183258 0.0101485577 0.009370447 0.00870604683 0.008132371455 0.00763223566
 0.007192538563 0.006803111764 0.00645549961 0.006144662114 0.00586404933 0.005610001839 0.005378735688
 0.005167993651 0.004974795563 0.004797153582 0.004633462056

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REFNO: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF 016-010 ARE AS FOLLOWS (IN UNITS OF INVERSE CM):

NUM:	12.2918039	23.8629876	35.3953574	46.99116333	58.4157136	69.9078007	81.3869559	92.8517913	104.300711	115.732011
	127.143936	138.53677	149.902411	161.245298	172.561482	183.849099	195.108274	206.331126	217.521768	228.676304
	239.792834	250.86945	261.904237	272.895275	283.840637	294.738389	305.586591			
NUM3:	14.1485942	25.8123557	37.3830985	48.9275206	60.455477	71.9692324	83.4687706	94.9531783	106.42113	117.871087
	129.301393	140.710318	152.096088	163.456897	174.790916	186.0936302	197.371196	208.61373	219.822024	230.994193
	242.12834	253.222566	264.274959	275.283603	286.246574	297.161942	308.027767			
NUM:	16.2529117	27.8241495	39.3566042	50.8729959	62.3772229	73.8694875	85.3488511	96.8134257	108.263116	119.69472
	131.109974	142.498077	153.866206	165.209517	176.526156	187.814259	199.071951	210.297352	221.488573	232.643719
	243.760889	254.838176	265.873666	276.865438	287.811564	298.710111	309.559138			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE CM) ARE AS FOLLOWS:

ELF:	3.36108467	18.3372061	44.2117875	81.5806506	130.437759	190.775219	262.583275	345.850311	440.56285	546.705958
	664.261195	793.210712	933.533148	1085.20568	1248.2036	1422.50032	1608.06737	1804.18744	2012.88915	2232.07747
	2462.4033	2703.82848	2956.31374	3219.81668	3494.25379	3779.69942	4075.98598			
ELG:	2.08429436	16.387638	42.2240464	79.5647634	128.397996	188.713787	260.50146	343.748924	438.44231	544.566475
	662.103738	791.035071	931.339472	1082.99408	1248.97416	1420.25311	1605.80245	1802.5918	2010.5889	2229.75958
	2460.06779	2701.47556	2953.94302	3217.42836	3491.88786	3777.27587	4073.5448			
ELM:	2.08429436	16.387638	42.2240464	79.5647634	128.397996	188.713787	260.50146	343.748924	438.44231	544.566475
	662.103738	791.035071	931.339472	1082.99408	1248.97416	1420.25311	1605.80245	1802.5918	2010.5889	2229.75958
	2460.06779	2701.47556	2953.94302	3217.42836	3491.88786	3777.27587	4073.5448			

THESE SUBM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

[illegible]

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REFNO = 4
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GMZ) OF
 O₁₀-O₁₆ ARE AS FOLLOWS:

FP: 56.2647579 58.44658 59.590792 60.434778 61.1505671 61.8001671 62.4112332 62.9979985 63.5685417 64.1277887
 64.6789165 65.2240749 65.7647579 66.3020496 66.8367513 67.36947 67.9006745 68.4307336 68.95599419 69.4889381
 70.0167183 70.5446452 71.072456 71.6002668 72.1281775 72.6562745 73.1846331

FM: 118.750331 62.4862673 60.306068 59.1642114 58.3238834 57.4124916 56.9682142 56.3633964 55.7838045 55.2213613
 54.6711395 54.1299606 53.5956808 53.0668 52.5422362 52.021188 51.5030486 50.9873483 50.4737203 49.9618682
 49.4515539 48.9425813 48.4347875 47.9280356 47.4222093 46.9172088 46.4129477

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAMERTZ
 RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.485573 491.289028 1265.84507 2385.2916 3849.27608 5657.49701 7809.6373 10305.3335 13144.1734 16325.6922
 19849.3707 23714.6348 27920.8549 32467.3457 37353.3687 42878.1172 48140.7464 54040.3426 60275.9387 66946.5105
 73750.977 80988.2 88556.9638 96456.0756 104684.164 113239.882 122121.801

ELM: 0 487.249341 1265.12998 2386.56217 3852.10176 5661.68468 7815.08032 10311.3681 13151.9582 16334.5986 19659.3785
 23725.7289 27933.024 32480.5809 37367.6602 42593.4655 48157.144 54057.786 60294.4249 66866.0372 73771.5422
 81009.802 88579.6215 96479.7478 104708.87 113269.621 122148.573

THE PREDICTED LMR AND RAMAN LINES CONNECTING
 STATES N=J WITH STATES N'=J'+N+2 (IN GMZ) ARE:

ERL1 430.985278 775.700436 1120.29033 1464.69927 1808.87153 2152.75136 2496.28295 2839.41048 3182.07803 3524.27964
 3865.80927 4206.74081 4547.02804 4886.55467 5225.28428 5563.16037 5900.12628 6236.12527 6571.10042 6904.99469
 7237.7509 7569.31168 7899.61953 8228.61674 8556.24544 8882.44757 9207.16486

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
 OBSERVED EXPERIMENTALLY ARE (IN GIGAMERTZ):

430.984697 775.6975 1120.3 1464.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.81
 THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 4 AND THOSE OBSERVED IS:
 0.0242705979 GMZ = 24.2705979 MHZ = 0.000809180003 INVERSE CM.

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THE PARAMETERS ACCORDING TO ALBRITTON, HARRUP, SCHMELIKOFF, AND ZARE
(REF. 5) ARE AS FOLLOWS:

B0 = -3.1010152 GMZ = 1.437708 INVERSE CMJ
B1 = -0.000150995497 GMZ = -4.84E-6 INVERSE CMJ
B2 = -1.13921134E-12 GMZ = -3.8E-14 INVERSE CMJ
LAMO = 59.53428527 GMZ = 1.98585 INVERSE CMJ
LAM1 = 0 GMZ = 0 INVERSE CMJ
WUO = -0.2529049176 GMZ = -0.008436 INVERSE CMJ
WU1 = 0 GMZ = 0 INVERSE CMJ

TEMP = 296 REFNO = 5 ISOTOPE = 66

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

IK,K+1,K+1

2.451932553 6.710310398 10.80295943 14.85054142 18.87963217 22.89923395 26.91333908 30.92397523 34.93228177
38.93894826 42.9441652 46.94892274 50.9528229 54.95617469 58.95905678 62.9615809 66.9638057 70.96579202 74.96756449
78.96916407 82.97060984 86.97192438 90.97312464 94.97422496 98.97523712 102.9761713 106.9770361
IK,K+1,K+1
2 6.538486807 10.73649664 14.81535008 18.85783037 22.88440263 26.90259653 30.91583566 34.92590143 38.93381249
42.94019357 46.9454912 50.94985258 54.9535542 58.95681576 62.95961569 66.96207235 70.96424509 74.9661803
78.96791481 82.96947819 86.97089449 90.97218343 94.97334138 98.97444199 102.9754368 106.9763555

IK,K+1,K+2,K+1

0.0480674729 0.0396894016 0.0304738973 0.0244588019 0.02036782853 0.01743271534 0.01523234938 0.01352477219
0.01216267896 0.011051742 0.01012892962 0.0093508927 0.008685561831 0.008111025123 0.007609887972 0.007169101666
0.00677853384 0.00643019475 0.006117716704 0.005835932799 0.005580434682 0.005348347788 0.005136180639
0.004941707621 0.004762878929 0.00459795061 0.004445429668

IK,K+1,K+2,K+1

0.3928604624 0.213063637 0.1447314862 0.112014398 0.09043164229 0.07413397845 0.06565722833 0.05773348292
0.0513223556 0.04654813775 0.0424599555 0.03903703361 0.03613864443 0.03365112616 0.03149359154 0.02960508494
0.0279388171 0.02644582476 0.02513443009 0.02394416864 0.02286861816 0.02189232961 0.02100251444 0.02018849666
0.01944129252 0.01875328972 0.01811799492

IK,K+1,K+2,K+2

0.1281798994 0.06380336295 0.04179277678 0.03108851453 0.02448827701 0.02048039285 0.01749767313 0.01527503682
0.01355592701 0.01218738467 0.01107261872 0.01014742209 0.009364753279 0.008701482891 0.008126242995 0.007624616434
0.007183485259 0.006792672984 0.006444164511 0.006131561666 0.005849695344 0.005594344147 0.00536202088 0.005149847282
0.004955376236 0.004776561344 0.004611656712

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T-1/306-3-14

REFNO = 5

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O16-016 ARE AS
FOLLOWS (IN UNITS OF INVERSE CM)

NUF:	12-2911194	23-8425555	35-3951905	49-9117578	58-161117	69-9085442	81-3880281	92-853259	104-302497	115-734198
	127-146558	138-537789	149-906084	161-249418	172-566559	183-855069	195-113304	206-339416	217-531557	228-687875
	239-806518	250-885631	261-92336	272-917849	283-867242	294-769683	305-623314			
NU3:	14-1691004	25-81327	37-3840592	48-9287333	60-4569394	71-9709405	83-4707204	94-9553689	106-423565	117-873778
	129-30436	140-713598	152-039724	163-460358	174-795492	186-101508	197-377175	208-62066	219-830123	231-003719
	242-139602	253-235924	264-290833	275-302478	286-269005	297-188561	308-05929			
NUM:	16-2543834	27-8258095	39-358455	50-8750218	62-3794057	73-8718082	85-3512921	96-816473	108-265761	119-697462
	131-109822	142-501053	153-869348	165-212882	176-529823	187-818333	199-076568	210-30268	221-494821	232-651139
	243-763782	254-848895	265-886624	276-881113	287-830506	298-732947	309-586578			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
CM) ARE AS FOLLOWS:

ELF:	3-963264	18-3396644	44-2147514	81-5843371	130-442383	190-780991	262-590403	345-859003	440-573316	546-718009
	664-275891	793-22791	933-553157	1086-22886	1248-23041	1422-5313	1608-10319	1804-91589	2012-93732	2232-13358
	2462-46887	2703-90597	2956-40417	3219-92332	3494-41981	3779-84855	4076-16242			
ELG:	2-08528301	16-3889419	42-2258826	79-5673616	128-401585	188-718595	260-507711	343-756843	438-452248	544-578429
	662-118088	791-052104	931-359517	1083-01752	1246-00147	1420-28426	1605-83932	1802-63464	2010-63876	2229-81774
	2460-13579	2701-55828	2954-0367	3217-5387	3492-01805	3777-42967	4073-72664			
ELM:	2-08528301	16-3889419	42-2258826	79-5673616	128-401585	188-718595	260-507711	343-756843	438-452248	544-578429
	662-118088	791-052104	931-359517	1083-01752	1246-00147	1420-28426	1605-83932	1802-63464	2010-63876	2229-81774
	2460-13579	2701-55828	2954-0367	3217-5387	3492-01805	3777-42967	4073-72664			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	368-478489	715-381116	1061-12112	1406-37912	1751-27187	2095-80543	2439-9517	2783-66918	3126-9102	3469-62396
		3811-79791	4153-25844	4494-07133	4834-14193	5173-4153	5511-83631	5849-34969	6185-90007	6521-43202	6855-89002
		7189-21854	7521-362	7852-26479	8181-87127	8510-12582	8836-97277	9162-35644			
NUG	(GMZ)	424-778943	773-842365	1120-7459	1466-84652	1812-45345	2157-63452	2502-38924	2846-69034	3190-49822	3533-76697
		3876-4472	4218-48747	4559-83501	4900-43625	5240-23703	5579-18284	5917-21885	6254-29005	6590-34128	6925-31727
		7259-16265	7591-82201	7923-23985	8253-30066	8582-12887	8909-48891	9235-38517			
NUM	(GMZ)	487-294155	834-196781	1175-93678	1525-19478	1870-08754	2214-62109	2558-76737	2902-44484	3245-72587	3588-43963
		3930-57357	4272-07411	4612-887	4952-9576	5292-23096	5630-85197	5968-16335	6304-7154	6640-24768	6974-70569
		7308-03421	7640-17766	7971-08045	8300-68694	8628-94149	8955-78843	9281-17211			

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REFNO = 3
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
 O1a=O1b ARE AS FOLLOWS:

FP:	56.3004538	58.8812494	59.624788	60.467059	61.1815823	61.8290861	62.4375431	63.0211663	63.5880162	64.1430052
	64.689298	65.2290292	65.7636742	66.2943144	66.8217349	67.3465303	67.8691575	68.3895731	68.9092597	69.4272439
	69.9441099	70.4600086	70.975065	71.4893835	72.0030519	72.5161448	73.0287257			
FMI	118.815666	62.5152118	60.3344162	59.1908806	58.3482598	57.6340833	56.9865795	56.3781226	55.7944994	55.2276444
	54.6726604	54.1263676	53.5866404	53.0519914	52.5213512	51.9939307	51.4691353	50.9465081	50.4256925	49.9064059
	49.3884217	48.8715557	48.355657	47.8406007	47.3262822	46.8126137	46.2999208			

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAEVOLT)
 RELATIVE TO THE GROUND STATE) ARE:

ELP:	62.5152118	491.328118	1265.90011	2385.36949	3849.38269	5657.64114	7809.82469	10305.5709	13144.4677	16326.0506
	19849.8009	23715.1455	27921.4559	32468.0486	37354.1844	42579.0689	48141.8517	54041.6271	60277.4335	66848.254
	73753.0156	80990.3898	88559.7924	96489.3834	104688.067	113244.493	122127.252			
ELM:	0	487.294155	1265.19048	2386.64602	3852.21601	5661.14614	7815.27566	10312.2139	13152.2612	16334.9659
	23726.2481	27933.6329	32481.2909	37368.4848	42594.4215	48158.2517	54059.0705	60295.9171	66867.7748	73773.5712
	81012.1782	88582.4118	96483.0322	104712.744	113270.196	122153.982				

THE PREDICTED LMR AND RAMAN LINES CONNECTING
 STATES N=J WITH STATES N'-J'=N+2 (IN GHZ) ARE:

ERL:	430.993701	775.715832	1120.312	1464.72738	1808.90595	2152.79201	2496.32982	2839.46366	3182.13785	3524.29662
	3865.88427	4206.84508	4547.12333	4885.66328	5225.40923	5563.30544	5900.2962	6236.32577	6571.33848	6905.27845
	7238.0901	7569.71766	7900.10539	8229.19756	8556.33844	8883.27229	9208.14338			

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
 OBSERVED EXPERIMENTALLY ARE (IN GIGAEVOLT):

430.984657	775.69975	1120.3	1464.63	1808.84	2152.77	2496.283	2839.4006	3182.07	3524.221	3865.81
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THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 5 AND THOSE OBSERVED IS:
 0.0578997886 GHZ = 57.8997886 MHZ = 0.00193132896 INVERSE CM.

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THE PARAMETERS ACCORDING TO TOMITA, WIZUSHIWA, HOWARD, AND EVENSON
(REF. 6) ARE AS FOLLOWS:

R0 = 3.100608 GMZ = 1.43767621 INVERSE CM
R1 = 0.000152 GMZ = 0.83350662E-6 INVERSE CM
R2 = 0 GMZ = 0 INVERSE CM

LAM0 = 59.501342 GMZ = 1.984751131 INVERSE CM
LAM1 = 5.847E-5 GMZ = 1.950349265E-6 INVERSE CM

WU0 = 0.2525865 GMZ = 0.008425378733 INVERSE CM
WU1 = 0.464E-7 GMZ = 0.219019306E-9 INVERSE CM

TEMP = 296 REFNO = 6 ISOPE = 66
K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)
2.451982489 6.710350595 10.0288899 14.8505637 18.8796492 22.8992495 26.9133482 30.92398223 34.93228638
38.93895076 42.9444171 46.9498159 50.95528504 54.9617027 58.9680096 62.9743735 66.9800096 70.98578193
74.98675509 78.99315137 82.9995587 86.97190916 90.97310823 94.97420727 98.97521821 102.9761512 106.9770147
I(K,K+1)K(K)
2 6.538619971 10.73656095 14.81537061 18.85785867 22.88442328 26.9026118 30.9158485 34.9259093 38.93381764
42.94019833 46.94544975 50.9505128 54.95535224 58.96081101 62.9660937 66.97206453 70.97842358 74.98616964
78.99490279 82.99946485 86.97087985 90.97216751 94.97334419 98.97442355 102.9754171 106.9763346

I(K,K+1)K(K+1)
0.04801751085 0.039649406 0.03044434557 0.02443630043 0.02035079666 0.01741971502 0.01522260807 0.0135177727
0.01215805965 0.01104924101 0.01012835181 0.009351785876 0.008688417254 0.008115448192 0.007615805751 0.00717455433
0.006787275904 0.006440289778 0.006129125397 0.005848432784 0.005594604663 0.0053633570502 0.005152642246
0.004959397219 0.004781788165 0.004618073367 0.004466761205

I(K,K+1)K(K+1)
0.392403193 0.2128491246 0.1465895832 0.11191253 0.09055533649 0.07607724526 0.06561526335 0.05770361711
0.05151267078 0.04653760694 0.0424535742 0.03904202823 0.03615052316 0.03366947377 0.03151807916 0.0296354532
0.027978447 0.02649974052 0.02518129848 0.02399627137 0.02292586122 0.02195463672 0.02106982449 0.0202607607
0.0195184732 0.01883335911 0.01820493352

I(K,K+1)K(K+2)K(K+2)
0.128046956 0.06343904736 0.04175224535 0.03103022277 0.02466763232 0.02046511974 0.01748648312 0.01526713151
0.01355077856 0.01218462667 0.01107198707 0.01014872067 0.009370818905 0.008706227903 0.008132562315 0.00763243745
0.007192749529 0.00680333314 0.006456181985 0.00614490489 0.005864338864 0.005610267026 0.00537921233 0.005164281948
0.004975049711 0.004797465784 0.004633786518

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REFNO = 0

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O16=O16 ARE AS
FOLLOWS (IN UNITS OF INVERSE CM):

NUF:	12.2917841	23.8629476	35.395291	46.911532	58.4155675	69.9076039	81.386937	92.8514611	104.300313	115.731593
	127.143428	138.53415	149.901909	161.244881	172.561232	183.849124	195.106712	206.332149	217.523584	228.679166
	239.797041	250.875355	261.912253	272.905878	283.854375	294.755886	305.608553			
NUG:	14.1685748	25.8125159	37.3830322	48.9274194	60.4553314	71.9690328	83.44685085	94.9528463	106.420731	117.870626
	125.300885	140.709791	155.095585	163.456479	174.790667	184.096328	197.371635	208.614753	219.82384	230.997054
	242.132547	253.228471	264.282974	275.294206	286.260311	297.179437	308.049729			
NUM:	16.2528919	27.8241094	39.3565377	50.8728946	62.3770771	73.8692877	85.3485889	96.8135956	108.262717	119.694259
	131.106466	142.497551	153.865703	165.209099	176.525907	187.814285	199.07239	210.298375	221.490389	232.64658
	243.765056	254.844082	265.881682	276.876041	287.825302	298.727607	309.581101			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
CM) ARE AS FOLLOWS:

ELF1	3.96108467	18.3371859	44.211727	81.5805235	130.437531	190.774844	242.5827	345.849474	440.561683	546.703982
	664.259167	793.208177	933.530087	1085.20211	1248.19961	1422.49609	1608.06317	1804.87064	2012.88641	2232.07654
	2462.40523	2703.83482	2956.32579	3219.83675	3494.32446	3779.74383	4076.04788			
ELG:	2.08429397	16.3876176	42.2239898	79.5646361	128.397767	188.713412	260.500885	343.748067	438.441264	544.564909
	662.101711	791.032536	931.33641	1082.99052	1245.97018	1420.24888	1605.79825	1802.58803	2010.58615	2229.75865
	2460.06973	2701.48171	2953.59507	3217.44842	3491.91853	3777.32028	4073.60671			
ELM:	2.08429397	16.3876176	42.2239898	79.5646361	128.397767	188.713412	260.500885	343.748067	438.441264	544.564909
	662.101711	791.032536	931.33641	1082.99052	1245.97018	1420.24888	1605.79825	1802.58803	2010.58615	2229.75865
	2460.06973	2701.48171	2953.59507	3217.44842	3491.91853	3777.32028	4073.60671			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	368.498417	715.393171	1061.12413	1406.37235	1751.25467	2095.77715	2439.91169	2783.61677	3126.84471	3469.54468
	3811.66409	4153.14935	4493.94618	4833.99992	5173.2556	5511.65809	5849.15209	6185.68221	6521.193	6855.62893
	7188.93444	7521.05394	7851.93181	8181.51241	8509.74008	8836.55915	9161.91394			
NUG	424.763186	773.839758	1120.71511	1466.80713	1812.40524	2157.57732	2502.32293	2846.61478	3190.41326	3533.67247
	3876.34302	4218.37342	4559.71094	4900.30197	5240.02736	5579.02756	5917.05276	6254.11294	6590.15294	6925.11746
	7258.95115	7591.59857	7923.00425	8253.11266	8581.86823	8909.2154	9235.09854			
NUM	487.249442	834.145816	1179.87932	1525.13101	1870.01773	2214.54553	2558.68632	2902.39858	3245.63461	3588.44361
	3930.47297	4271.9691	4612.77774	4952.8442	5292.11354	5630.53061	5968.04011	6304.58667	6640.11481	6974.54902
	7307.89374	7640.03237	7970.9323	8300.53488	8628.78546	8955.62837	9281.00792			

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REFNO = 6

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
O1=U16 ARE AS FOLLOWS:

FP:	56.267695	58.4465871	59.5909848	60.4347834	61.1505718	61.8001717	62.4112376	62.9980032	63.5685458	64.1277927
	64.6789221	65.2240781	65.7647605	66.3020515	66.8367523	67.3694699	67.9004732	68.4307308	68.9559375	69.4885318
	70.0167097	70.5446343	71.0724424	71.6002502	72.1281576	72.6562509	73.1846056			
FM:	118.750321	62.4862556	60.306058	59.1642058	58.3238784	57.6124869	56.9482096	56.3633919	55.7838002	55.2213572
	54.6711356 <td>54.125957 <td>53.5956776 <td>53.0667974 <td>52.5422343 <td>52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td></td></td></td></td></td>	54.125957 <td>53.5956776 <td>53.0667974 <td>52.5422343 <td>52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td></td></td></td></td>	53.5956776 <td>53.0667974 <td>52.5422343 <td>52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td></td></td></td>	53.0667974 <td>52.5422343 <td>52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td></td></td>	52.5422343 <td>52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td></td>	52.021187 <td>51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td></td>	51.5030486 <td>50.9873502 <td>50.4737231 <td>49.9618727</td> </td></td>	50.9873502 <td>50.4737231 <td>49.9618727</td> </td>	50.4737231 <td>49.9618727</td>	49.9618727
	49.4515602 <td>48.9425898 <td>48.4347984 <td>47.9280492 <td>47.4222259 <td>46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td></td></td></td></td></td>	48.9425898 <td>48.4347984 <td>47.9280492 <td>47.4222259 <td>46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td></td></td></td></td>	48.4347984 <td>47.9280492 <td>47.4222259 <td>46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td></td></td></td>	47.9280492 <td>47.4222259 <td>46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td></td></td>	47.4222259 <td>46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td></td>	46.9172287 <td>46.4129712 <td></td> <td></td> <td></td> </td>	46.4129712 <td></td> <td></td> <td></td>			

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAEVOLT)
RELATIVE TO THE GROUND STATE) ARE:

ELP:	62.4855614	491.288416	1265.84325	2385.28778	3849.26822	5657.48578	7809.62007	10305.3084	13144.1384	16325.6452
	19849.3099	23714.5588	27920.7632	32467.2389	37953.2463	42577.9904	48147.8203	54040.2297	60275.8564	66846.4827
	73751.035	80988.3841	88557.348	96456.6771	104685.084	113241.213	122123.657			
ELM:	0	487.244748	1265.12817	2386.85836	3852.09492	5661.67346	7815.0631	10311.943	13151.9232	16324.5517
	23725.6529	27932.9323	32480.4741	37367.5408	42593.3387	48157.0179	54057.6731	60294.3426	66866.0094	73771.6002
	81009.9862	88579.9827	96480.3493	104709.79	113266.952	122150.428				

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'=J'+N+2 (IN GHZ) ARE:

ERL:	430.984672	775.699229	1120.28833	1464.69623	1808.86716	2152.74536	2496.27509	2839.40057	3182.06607	3524.21581
	3868.79405	4206.74502	4547.01298	4886.54215	5229.27679	5563.16114	5900.13944	6236.15594	6571.15487	6905.08049
	7237.87703	7569.48874	7899.85986	8228.93463	8556.6573	8882.97212	9207.82331			

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
OBSERVED EXPERIMENTALLY ARE (IN GIGAEVOLT):

430.984697 775.6975 1120.3 1464.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.81
THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 6 AND THOSE OBSERVED IS:
0.0237967896 GHZ = 23.7967896 MHZ = 0.00079377546 INVERSE CM.

THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR O16=016:

R0 = 43.10046 GMZ = 1.437676594 INVERSE CMJ
R1 = -0.00014501 GMZ = -0.0003701294E-6 INVERSE CMJ
R2 = 0 GMZ = 0 INVERSE CMJ

LAM0 = 59.501341 GMZ = 1.984751097 INVERSE CMJ
LAM1 = 5.848E-5 GMZ = 1.950682829E-6 INVERSE CMJ

MU0 = -0.252586 GMZ = -0.008425362055 INVERSE CMJ
MU1 = -2.47E-7 GMZ = -8.239033151E-9 INVERSE CMJ

TEMP = 296 REFNO = 7 ISOTOPE = 66

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)

2.451982494 6.710350609 10.86288901 14.85056373 18.87944924 22.899247 26.91344848 30.92344229 34.93224446
38.93895084 42.94441719 46.94981164 50.95285015 54.95617038 58.95905098 62.96157368 66.9638011 70.96578205
74.96755524 78.96915153 82.97059605 86.97190934 90.97310842 94.97420747 98.97521843 102.9761514 106.977015

I(K,K-1)K(K)

2 6.453661985 10.73656097 14.81539064 18.8578587 22.88442332 26.90261186 30.91584691 34.92590941 38.93381772
42.94019641 46.94544985 50.94985138 54.95359246 58.95681114 62.9596095 66.9620467 70.96423597 74.9661698
78.96790296 82.96946503 86.97088003 90.97216771 94.9733444 98.97442377 102.9754173 106.9763348

I(K,K)K+2,K+1

0.04801750574 0.03964939083 0.03044422343 0.02443627 0.02035075795 0.01741966803 0.01522253279 0.01351770909
0.0121579877 0.0110491606 0.01012826303 0.009351688615 0.008688311458 0.008115333765 0.00761568271 0.007176323669
0.006787135344 0.006440140344 0.006128967005 0.005848465345 0.005594428082 0.00536338468 0.005152447077 0.004954192592

I(K,K+1)K+2,K+1

0.3924602786 0.2128490511 0.144589477 0.1119123908 0.0905557444 0.07607704021 0.0651502519 0.05770334572
0.051512366 0.0445372682 0.04245320216 0.03904162226 0.03615008305 0.03368899927 0.03151757002 0.02963490913
0.02797426541 0.0264991457 0.02518044778 0.02399358444 0.02292513767 0.02195387615 0.02106502646 0.02025942478
0.0195175989 0.01883444594 0.01820398096

I(K,K+1)K+2,K+2

0.1280466821 0.04343902523 0.04175221499 0.03103018413 0.0246675854 0.02046506454 0.01748641962 0.01526705468
0.01355069836 0.01218453807 0.01107189002 0.01014461512 0.009370504803 0.008706105189 0.008132430925 0.007632297314
0.007192600572 0.006803175282 0.00645601514 0.006144723068 0.00586415377 0.005610072637 0.00537900858 0.005164068702
0.004974826852 0.004797233185 0.004633544048

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REFNO = 7
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O16=O16 ARE A8 FOLLOWS (IN UNITS OF INVERSE CM):

NUF:	12.2917847	23.8629518	35.3953043	46.9115624	58.4156257	69.9076988	81.3888469	92.8516474	104.300632	115.731988
	127.144004	138.534894	149.90285	161.246052	172.562669	183.850862	195.108792	206.334612	217.526475	228.682531
	239.80093	250.87982	261.917348	272.91166	283.860902	294.76322	305.616758			
NUG:	14.1685253	25.81252	37.3830454	48.9274496	60.455389	71.9691304	83.4686615	94.9530743	106.42105	117.871061
	140.710535	152.096527	163.457651	174.792103	186.098066	197.373715	208.617216	219.826731	231.00042	242.136438
	253.232937	264.288071	275.299989	286.26684	297.186774	308.057937				
NUM:	16.2528925	27.8241136	39.3565511	50.872925	62.3771349	73.8693856	85.3487422	96.8138219	108.263037	119.694694
	131.107042	142.4498295	153.866645	165.210271	176.527343	187.816023	199.07447	210.300838	221.49328	232.644947
	243.768987	254.848548	265.856778	276.881424	287.83183	298.734943	309.589308			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE CM) ARE AS FOLLOWS:

ELF:	3.96108462	18.3371865	44.2117319	51.5805419	130.43758	190.774951	262.582505	345.849833	440.562268	546.704887
	64.260508	793.210093	933.532747	1085.20572	1248.20439	1422.5023	1608.07112	1804.88066	2012.8989	2232.09192
	2462.42398	2703.85746	2956.35289	3219.86895	3494.36244	3779.78833	4076.09972			
ELG:	2.084294	16.3876183	42.2239908	79.5646547	128.357816	188.71352	260.501091	343.748446	438.44185	544.565814
	662.103051	791.034452	931.339071	1082.99412	1245.97495	1420.25509	1605.80419	1802.59806	2010.59864	2229.77403
	2460.08847	2701.50434	2953.98217	3217.48062	3491.9565	3777.36478	4073.65884			
ELM:	2.084294	16.3876183	42.2239908	79.5646547	128.357816	188.71352	260.501091	343.748446	438.44185	544.565814
	662.103051	791.034452	931.339071	1082.99412	1245.97495	1420.25509	1605.80419	1802.59806	2010.59864	2229.77403
	2460.08847	2701.50434	2953.98217	3217.48062	3491.9565	3777.36478	4073.65884			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	364.498434	715.393298	1041.12453	1406.37326	1751.2564	2095.78009	2439.91629	2783.62356	3126.85429	3469.55772
		3811.68135	4153.17164	4493.9744	4834.03503	5173.29866	5511.71019	5849.21443	6185.75605	6521.27966	6855.72982
		7189.05104	7521.1878	7882.08495	8181.68573	8509.93575	8836.77902	9162.15992			
NUG	(GMZ)	424.763201	773.439882	1120.71951	1466.80804	1812.40697	2157.58025	2502.32752	2846.62155	3190.42283	3533.68551
		3876.36027	4218.39571	4559.73916	4900.33708	5240.13541	5579.07967	5917.11511	6254.18679	6590.23961	6925.21837
		7259.06778	7591.73247	7923.15704	8253.28603	8582.06397	8909.43534	9235.3446			
NUM	(GMZ)	487.249458	834.145942	1179.87972	1525.13192	1870.01946	2214.54847	2558.69092	2902.40537	3245.64419	3588.35665
		3930.49024	4271.9514	4612.80597	4952.87933	5292.15661	5630.58273	5968.10247	6304.66052	6640.20149	6974.66994
		7308.01037	7640.16726	7971.08508	8300.70828	8628.98118	8955.84828	9281.25395			

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REFNO = 7
 INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN MHZ) OF
 016-016 ARE AS FOLLOWS:

FP: 56.2647671 58.4465835 59.5909801 60.4347778 61.1505654 61.8001648 62.4112304 62.997996 63.5685389 64.1277864
 64.6789168 65.2240741 65.7647884 66.3020516 66.8367551 67.369476 67.900683 68.430745 68.9599866 69.4886564
 70.0167406 70.544672 71.0724876 71.6003038 72.1282203 72.6563234 73.1846888
 FM: 114.750329 62.4862566 60.3060604 59.1642098 58.3238838 57.6124937 56.9682178 56.3634013 55.7838104 55.2213685
 54.6711476 54.1299695 53.5956903 53.06681 52.5422465 52.0211985 51.503059 50.9873591 50.4737301 49.9618773
 49.451562 48.9425882 48.4347929 47.9280392 47.4222108 46.9172079 46.4129441

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAELECTRONVOLTS)
 RELATIVE TO THE GROUND STATE) ARE:

ELP: 62.4855623 491.288437 1265.8434 2385.28834 3849.2497 5657.48899 7809.62623 10305.3192 13144.156 16325.6724
 19849.3601 23714.6163 27920.8429 32467.3468 37333.3894 42578.1766 48140.8586 54040.5303 60276.2309 66846.9438
 73751.597 80989.0627 88558.1979 96457.6423 104686.222 113242.547 122125.211
 ELM: 0 487.248764 1265.12432 2386.55891 3852.09638 5661.67466 7815.06924 10311.9537 13151.9407 16334.8788 19859.3579
 23725.7104 27933.012 32480.5821 37367.6839 42593.5248 48157.2562 54057.9737 60294.7171 66846.9405 73772.1622
 81010.6648 88580.7952 96481.3148 104710.928 113268.286 122151.982

THE PREDICTED LMR AND RAMAN LINES CONNECTING
 STATES N=J WITH STATES N'=J'+N+2 (IN MHZ) ARE:

ERL: 430.984691 775.699359 1120.28874 1464.69714 1808.86889 2152.7483 2496.27969 2839.40737 3182.07566 3524.22887
 3865.81132 4206.76733 4547.04121 4886.57728 5226.31985 5563.21325 5900.20179 6236.22978 6571.24153 6905.19138
 7237.99363 7569.62259 7900.01259 8229.10794 8556.85296 8883.19196 9208.06326

THE CORRESPONDING LASER MAGNETIC RESONANCE OR RAMAN LINES
 OBSERVED EXPERIMENTALLY ARE (IN GIGAELECTRONVOLTS):

430.984697 775.69975 1120.3 1464.63 1808.84 2152.77 2496.283 2839.4006 3182.07 3524.221 3865.81
 THE RMS DIFFERENCE BETWEEN RAMAN FREQUENCIES PREDICTED BY REF. 7 AND THOSE OBSERVED IS:
 0.023542255 MHZ = 23.542255 MHZ = 0.000 85285099 INVERSE CM.

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THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GOROV (1975),
REF. 7, ARE AS FOLLOWS FOR 016-018:

R0 = 0.707406 GMZ = 1.357852972 INVERSE CM
R1 = 0.00129 GMZ = -0.302976828F-6 INVERSE CM
R2 = 0 GMZ = 0 INVERSE CM

LAM0 = 5.312E-5 GMZ = 1.984676246 INVERSE CM
LAM1 = 5.312E-5 GMZ = 1.771892474F-6 INVERSE CM

MU0 = -0.238488 GMZ = -0.00795510339 INVERSE CM
MU1 = -6.13E-7 GMZ = -2.084761749E-8 INVERSE CM

TEMP = 296 REFNO = 7 ISOTOPE = 68
K = 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
34 35 36 37 38 39

I(K,K+1)K(K)

0 2.446198334 4.615752304 6.705561725 8.761263232 10.79921037 12.82673301 14.84761116 16.86339319 18.87719084
20.88805071 22.89714345 24.90486797 26.91151147 28.91728599 30.92235153 32.92683105 34.93082063 36.93433964
38.93761962 40.94033985 42.94319787 44.94562744 46.94785676 48.94990358 50.95180602 52.95356328 54.95519609
56.95671719 58.95813766 60.95946712 62.96071403 64.96188582 66.96298907 68.96402959 70.96501257 72.96594263
74.96682392 76.96766016 78.9684547

I(K,K+1)K(K)

0 2 4.22386818 6.523195558 8.654535571 10.72889876 12.77684221 14.81034565 16.83508707 18.85410941 20.86919157
22.88144349 24.89139376 26.90014055 28.90743603 30.91373625 32.91923182 34.92406761 36.92835566 38.93218399
40.93562272 42.93872841 44.94154715 46.94411692 48.94646327 50.94863084 52.95062334 54.95246635 56.95417589
58.95576592 60.95724852 62.9586342 64.95993815 66.9611504 68.96229607 70.96337543 72.96439405 74.96535691
76.96627684 78.96713262

I(K,K+2)K(K+1)

0 0.0538016567 0.0509143628 0.04443827522 0.03873676789 0.03412296277 0.03040984941 0.02738883993 0.02489570295
0.02280912326 0.02104019776 0.01952321971 0.01820895648 0.01705996352 0.01604734018 0.01514846881 0.01434541979
0.01362381097 0.01297198005 0.01238037594 0.01184110501 0.0113475887 0.01089430205 0.01047657189 0.01009041947
0.009732434558 0.009399687109 0.009089623449 0.008800047735 0.008529010289 0.00827481733 0.008039971163 0.007811146348
0.007599165675 0.007398980046 0.00720151539 0.007030339091 0.006860286326 0.00669881181 0.006545237004

I(K,K+1)K(K+2)K(K+1)

0.776197794 0.4386984831 0.3084481116 0.238386878 0.1944381872 0.1642461838 0.1422090174 0.1254095305 0.1121762474
0.101481457 0.09265887135 0.085256064 0.07893613672 0.07352994791 0.06880777085 0.06466119556 0.06094912722
0.0572051315 0.05478737348 0.05214234834 0.04974516501 0.04756272596 0.04556757849 0.04373676014 0.04205091671
0.04049361972 0.03905083396 0.0377104968 0.03646218331 0.03529683747 0.034208546 0.03318440398 0.032242834
0.03132079868 0.03046916438 0.02966511982 0.0289045928 0.02818497283 0.02750239621 0.02685446408

I(K,K+1)K(K+2)K(K+1)

0.2756131817 0.1434711084 0.095466442927 0.07110124036 0.0564911194 0.0467920602 0.0399162735 0.03477474727
0.0308084324 0.02764742213 0.02507290234 0.02293637001 0.02113539592 0.0195970863 0.018241744 0.017145449
0.01608878678 0.01518443324 0.01437727789 0.0136525449 0.01299830391 0.01240481746 0.01186406 0.0113673507
0.01091511721 0.01049661306 0.010104982831 0.00975132554 0.009418146326 0.009107730676 0.00881452217 0.00854564416
0.008292163633 0.00805314807 0.007828169248 0.007616064328 0.007415774348 0.007226358431 0.007046974077
0.006876859892

REFNO = /
 INPUT: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
 33 34 35 36 37 38 39

THE SUBMILLIMETER TRANSITIONS OF O16-O18 ARE AS
 FOLLOWS (IN UNITS OF INVERSE CM):

NUF: 0 11.5085583 16.9782804 27.4332147 27.809008 33.3240663 38.7638636 44.2008027 49.635091 55.0667776 60.4958227
 65.922134 71.3455817 76.7660197 82.1832836 87.5971991 93.0075849 98.4142539 103.817015 109.215676 114.610038
 119.999904 125.385076 130.765351 136.140529 141.510407 146.874783 152.233453 157.586213 162.93286 168.273188
 173.606354 178.934071 184.254216 189.567223 194.872884 200.171001 205.461361 210.743761 216.017996
 NUG: 7.80360459 13.4006023 18.9096143 24.3897405 29.8563868 35.3150944 40.7684152 46.2175756 51.6631968 57.1055838
 62.5444633 67.9810553 73.411124 78.833944 84.2704288 89.6934251 95.1127768 100.528316 105.933863 111.347253
 116.750283 122.148768 127.542517 132.931335 138.315024 143.693391 149.066231 154.43344 159.794535 165.149596
 170.498328 175.840526 181.175989 186.504512 191.825892 197.139924 202.446404 207.745127 213.03589 218.318486
 NUM: 9.0559302 15.4699833 20.9397261 26.3946879 31.8424085 37.2856152 42.7254607 48.1624549 53.5968051 59.0285605
 64.4574813 69.8840742 75.3076123 80.7261467 86.1455138 91.5595394 96.9700421 102.376835 107.77927 113.178525
 118.573032 123.96305 129.348379 134.72882 140.10417 145.474227 150.838789 156.197651 161.550611 166.89744
 172.238006 177.572031 182.899336 188.219715 193.532962 198.838873 204.137243 209.427864 214.710533 219.985043

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE
 CM) ARE AS FOLLOWS:

ELF: 0 4.5247102 9.95599302 18.1026533 28.9643852 42.5407754 58.8313077 77.8353625 99.5522168 123.981044 151.120916
 180.970799 213.529557 248.795551 286.768638 327.446173 370.827007 416.909486 465.691857 517.172259 571.348731
 628.219207 687.781518 750.33392 814.972455 882.596228 952.902129 1025.88477 1101.54947 1179.88523 1260.89176
 1344.56596 1430.90463 1519.9044 1611.56204 1705.87358 1802.83634 1902.44571 2004.69418 2109.58981
 ELG: 0 2.63267001 8.0246591 16.140875 26.9888992 40.5497473 56.8267561 75.8185895 97.5241109 121.942238 149.071875
 176.911876 211.461026 246.718026 284.681493 325.349947 368.721815 414.795424 463.589003 515.040882 569.208486
 626.070343 685.624076 747.667408 812.797359 880.413245 950.710681 1023.68758 1099.34115 1177.68849 1258.66662
 1342.33243 1428.66271 1517.65416 1609.30338 1703.60684 1800.56093 1900.16195 2002.40605 2107.28932
 ELM: 0 2.63267001 8.0246591 16.140875 26.9888992 40.5497473 56.8267561 75.8185895 97.5241109 121.942238 149.071875
 176.911876 211.461026 246.718026 284.681493 325.349947 368.721815 414.795424 463.589003 515.040882 569.208486
 626.070343 685.624076 747.667408 812.797359 880.413245 950.710681 1023.68758 1099.34115 1177.68849 1258.66662
 1342.33243 1428.66271 1517.65416 1609.30338 1703.60684 1800.56093 1900.16195 2002.40605 2107.28932

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF (GMZ)
 0 345.017897 508.99604 672.530856 835.848379 999.030374 1162.11139 1325.10673 1488.02259 1650.86044 1813.61914
 1976.29583 2138.88673 2301.38738 2463.79286 2626.09796 2788.29725 2950.38511 3112.35562 3274.20358 3435.92249
 3597.50663 3758.95 3920.2464 4081.39038 4242.37529 4403.15523 4563.84411 4724.31583 4884.60426 5044.70327
 NUG (GMZ)
 5204.60673 5364.3285 5523.80243 5683.08236 5842.14215 6000.97563 6159.57664 6317.93902 6476.05659
 233.94618 401.739949 566.895974 731.187224 895.071957 1058.7199 1222.20634 1385.56806 1548.82368 1711.98233
 1875.04783 2038.02077 2200.89973 2363.68198 2526.3639 2688.94124 2851.40931 3013.76311 3175.99737 3338.10467
 3500.08542 3661.92794 3823.62847 3985.18118 4146.58015 4307.81948 4468.89317 4629.79523 4790.51964 4951.06034

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NUM 5111.1127 5271.56636 5431.5195 5591.2646 5750.79555 5910.10423 6049.1905 6228.04224 6386.65531 6545.02356

(GMZ) 298.73162 463.778433 627.757195 791.292836 954.611391 1117.79462 1280.87709 1443.87407 1606.79179 1769.63173
1932.39267 2095.07184 2257.64542 2420.16895 2582.57753 2744.88594 2907.08873 3069.1803 3231.15494 3393.00882
3554.73007 3716.31874 3877.76886 4039.06841 4200.21735 4361.20761 4522.03312 4682.68778 4843.16548 5003.4601
5163.56551 5323.47557 5483.18415 5642.68509 5801.97224 5961.23946 6119.88057 6278.48942 6436.85594 6594.98567

REFNO = 7

NUMPUT: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
33 34 35 36 37 38 39

THE MICROWAVE TRANSITION FREQUENCIES (IN GMZ) OF
O16=018 ARE AS FOLLOWS:

FM: 0 56.7220524 57.8929344 58.6563677 59.223578 59.6895224 60.0949461 60.4613313 60.8010839 61.1218718 61.4286909
61.7249364 62.012997 62.2946028 62.5710377 62.8432748 63.1120656 63.3779997 63.6415466 63.9030845 64.1629223
64.4213144 64.6784724 64.9345742 65.1897702 65.4441888 65.69794 65.9511191 66.203809 66.456082 66.7080019 66.959625
67.2110014 67.4621756 67.7131878 67.9640741 68.214867 68.4655961 68.7162886 68.966969
FM: 0 118.759917 64.5269817 62.0384837 60.8612206 60.1056124 59.0747249 58.670773 58.3060124 57.9681164
57.6493914 57.3448415 57.0510715 56.7656326 56.4869749 56.2136344 55.9446979 55.679414 55.171931 55.1575658
54.9001536 54.6446479 54.3907943 54.1383809 53.88723 53.6371913 53.3881363 53.1399545 52.8925518 52.6458444
52.3997601 52.1542351 51.9092133 51.6646446 51.4204842 51.1766921 50.9332323 50.6900721 50.447182

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAHERTZ
RELATIVE TO THE GROUND STATE) ARE:

ELP: 54.2331418 24.6923196 186.340086 429.814385 754.873703 1161.44177 1649.39015 2218.75099 2869.46615 3601.50319
414.82925 5309.40998 6285.20893 7342.18722 8480.30331 9699.51289 10999.7688 12381.0508 13843.216 15386.298
17010.208 18714.8836 20500.2596 22366.2677 24312.8366 26339.8919 28447.3561 30635.1484 32903.1854 35251.3801
37679.6428 40187.8804 42775.9974 45443.894 48191.4683 51018.615 53925.2257 56911.1845 59976.39 63120.7113
ELM: 54.2331418 37.3455452 179.713038 426.432269 753.23604 1161.00161 1649.94566 2220.13759 2871.59844 3604.31905
418.28983 5313.48552 6289.87708 7347.43075 8486.10865 9705.86919 11006.6672 12388.4541 13851.1781 15394.7839
17019.2133 18724.4047 20510.2934 22376.8115 24323.888 26351.4489 28459.4168 30647.7114 32916.2492 35264.9437
37693.705 40202.4405 42791.0541 45459.447 48207.5169 51035.1586 53942.2639 56928.7212 59994.4162 63139.2311

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'=J'+N+2 (IN GMZ) ARE:

ERL: 244.24002 407.05638 569.85724 732.63649 895.387813 1058.1051 1220.78214 1383.41274 1545.99071 1708.50471
1870.96398 2033.3449 2195.65242 2357.87435 2520.00649 2682.04266 2843.97666 3005.8023 3167.51339 3329.12373
3490.56714 3651.89742 3813.08838 3974.13383 4135.02758 4295.76342 4456.33518 4616.73666 4776.96167 4937.20402
5096.8575 5256.51594 5415.97314 5575.22291 5734.25906 5893.07538 6051.6657 6210.02382 6368.11435 6525.50144

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THE PARAMETERS OF MOLECULAR OXYGEN ACCORDING TO STEINBACH AND GORDY (1975),
REF. 7, ARE AS FOLLOWS FOR O18=018:

R0 = 38.31373 GMZ = 1.278008468 INVERSE CMJ
R1 = -0.000115 GMZ = -3.835987095E-6 INVERSE CMJ
R2 = 0 GMZ = 0 INVERSE CMJ

LAM0 = 59.496658 GMZ = 1.584596224 INVERSE CMJ
LAM1 = 5.211E-5 GMZ = 1.7382025E-6 INVERSE CMJ

MU0 = -0.224439 GMZ = -0.007486479194 INVERSE CMJ
MU1 = -3.51E-7 GMZ = -1.170809974E-8 INVERSE CMJ

TEMP = 296 REFNO = 7 ISOTOPE = 88

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)

2.439329238 6.499814898 10.79482301 14.14408852 18.47425722 22.89463278 26.90311812 30.92040457 34.92907031
38.93602977 42.94174138 46.94651283 50.95055832 54.95403157 58.95704575 62.95948604 66.96201774 70.96403186
74.96594865 78.96762044 82.96913344 86.97050914 90.9717653 94.97291675 98.97397597 102.9749535 106.9758584

I(K,K+1)K(K)

2 6.504877968 10.71976784 14.80432871 18.84963621 22.87788755 26.89719096 30.91121671 34.92186869 38.93023317
42.93697519 46.94292474 50.94717218 54.95112068 58.95451663 62.95746821 66.9600571 70.9623461 74.9643843 78.96621064
82.96785637 86.96934691 90.9707031 94.97194221 98.97307868 102.9741247 106.9750905

I(K,K+2)K(K+1)

0.06067076183 0.05014510241 0.03851031879 0.03091148398 0.02574277528 0.02203388254 0.01925331333 0.01709543128
0.01537413188 0.0139702289 0.0128040739 0.01182050365 0.01098014123 0.01025414558 0.009620913863 0.009063957777
0.008570470644 0.008130359069 0.007735561107 0.007379560416 0.007057033318 0.006763588234 0.006495570518
0.006249914307 0.006024028705 0.005815703375 0.005623069151

I(K,K+1)K(K+1)

0.4933198775 0.268771928 0.1862888108 0.1415056267 0.1145161729 0.09620334192 0.08297671577 0.07296720524
0.06513289983 0.05883591923 0.05366567463 0.04934588714 0.04568380927 0.04254086893 0.03981488265 0.0374244454
0.03532362675 0.03348306572 0.03178060269 0.03027690638 0.02891816751 0.02766486631 0.02656064081 0.02553259841
0.02458878625 0.02371978353 0.02291738357

I(K,K+1)K(K+2)

0.1617886982 0.08023216386 0.05281415149 0.03925267807 0.03120336398 0.0258859599 0.0221166266 0.01930778127
0.01713525535 0.01540576621 0.0139970004 0.01282781614 0.01184228465 0.01100061488 0.01027372337 0.009633569073
0.009082472786 0.008588672746 0.008148338796 0.007753384302 0.00739727599 0.007074678339 0.006781191349 0.006513154293
0.00626796852 0.006041624834 0.005833331428

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REFNO = 7

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF O18=O18 ARE AS FOLLOWS (IN UNITS OF INVERSE CM)

NUF:	10.727142	21.0041762	31.2529109	41.4895538	51.7168826	61.934824	72.1424101	82.3391046	92.5230323	102.693039
	112.84773	122.985683	133.10542	143.20562	153.284705	163.341257	173.373816	183.380917	193.361096	203.312884
	213.234815	223.125419	232.983226	242.806768	252.594573	262.345171	272.057091			
NU01	12.4364625	22.9688603	33.248005	43.5078406	53.7552159	63.9916419	74.2169814	84.4304492	94.6309632	104.817289
	114.988107	125.142049	135.277715	145.393084	155.488523	165.560789	175.609032	185.631797	195.627626	205.595058
	215.532631	225.438878	235.312336	245.151536	255.955011	264.721294	274.448914			
NUM:	14.6888776	24.9659575	35.2147674	45.4515427	55.6789714	65.8970725	76.1050407	86.3017472	96.4859141	106.656188
	116.811172	126.949447	137.069574	147.170109	157.249556	167.306579	177.339596	187.347182	197.327874	207.280203
	217.202701	227.093899	236.952329	246.774652	256.565002	266.316304	276.028955			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE CM) ARE AS FOLLOWS:

ELF:	3.9617129	16.7412722	39.7425457	72.9622191	116.395505	170.036143	233.8744	307.907049	392.117472	486.495455
	591.027394	705.698189	820.49127	945.388591	1110.37084	1285.41641	1430.50346	1605.60784	1790.70414	1985.76549
	2190.76352	2405.6684	2630.44884	2865.07206	3109.50381	3363.70837	3627.64856			
EL0:	2.05239461	14.7765882	37.7474517	70.9439622	114.357172	167.979327	231.802029	305.815725	390.009541	484.371206
	588.887017	703.541823	828.319017	963.200527	1108.16682	1263.19688	1428.26824	1603.35696	1788.43761	1983.48331
	2188.4657	2403.35494	2628.11973	2862.72729	3107.14337	3361.33225	3625.25673			
ELM:	2.05239461	14.7765882	37.7474517	70.9439622	114.357172	167.979327	231.802029	305.815725	390.009541	484.371206
	588.887017	703.541823	828.319017	963.200527	1108.16682	1263.19688	1428.26824	1603.35696	1788.43761	1983.48331
	2188.4657	2403.35494	2628.11973	2862.72729	3107.14337	3361.33225	3625.25673			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	321.591694	629.689362	936.938699	1243.82643	1550.43313	1856.75938	2162.78104	2468.46426	2773.77073	3078.65987
		3383.08983	3687.01802	3990.40136	4293.19649	4596.35984	4896.84749	5197.61624	5497.6216	5796.81982	6095.16693
		6392.61893	6689.13178	6984.66141	7279.16378	7572.5948	7864.91037	8156.0664			
NU0	(GMZ)	378.831616	688.589107	994.750114	1304.33225	1611.54083	1918.42116	2224.96913	2531.16119	2836.96491	3142.34326
		3447.25672	3751.66424	4055.52386	4358.79299	4661.42866	4963.3876	5264.62634	5565.10128	5864.76869	6163.58479
		6461.50571	6758.48755	7054.48634	7349.45816	7643.35895	7936.14473	8227.77145			
NUM	(GMZ)	440.361473	748.460577	1055.71217	1362.60297	1669.21357	1975.54453	2281.57172	2587.26129	2892.57493	3197.47207
		3501.91085	3805.84866	4109.24246	4412.04886	4714.2243	5015.72506	5316.50794	5616.52724	5915.74084	6214.10414
		6511.57315	6808.10382	7103.65211	7398.17394	7691.62525	7983.96193	8275.13989			

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REFNO = 7

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GHZ) OF
018-018 ARE AS FOLLOWS:

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53		
FP:	57.2339223	58.8997449	59.6114131	60.2058186	61.1076961	61.6617782	62.1880871	62.696935	63.1941781	63.6833923																			
	64.1668875	64.642245	65.1224977	65.5964993	66.0688177	66.5399008	67.010065	67.4796801	67.9488733	68.4178573																			
	68.8867822	69.3557745	69.8249414	70.2943757	70.76415	71.2343584	71.7050407																						
FM:	118.769165	61.5298572	59.8714492	58.9620532	58.2707236	57.6727397	57.1233711	56.6025552	56.1001002	55.6100297																			
	55.1288077	54.6541245	54.1844193	53.7185974	53.255867	52.7956395	52.337467	51.8810016	51.425968	50.9721445																			
	50.5193501	50.0474343	49.616271	49.1857526	48.75157867	48.2662928	47.8171998																						

THE RESPECTIVE LOWER STATE ENERGIES (IN BIGAMERT2
RELATIVE TO THE GROUND STATE) ARE:

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53		
ELP:	61.5292425	442.990971	1131.44013	2126.84448	3428.34176	5035.89355	6949.24999	9168.12478	11492.1919	14521.0834																			
	17454.3886	21091.6532	24832.3794	28876.0254	33222.0054	37869.6898	42818.4048	48067.4324	53616.0108	59463.3338																			
	65008.5511	72050.7685	78789.0474	85822.4051	93149.8149	100770.204	108682.463																						
ELM:	0	440.360858	1131.58008	2128.39025	3431.17873	5039.88259	6954.31471	9174.21912	11699.286	14529.1568	17663.4267																		
	21101.6453	24843.3175	28887.9033	33234.8184	37883.4341	42833.0774	48083.0311	53632.5337	59480.7795	65686.9186																			
	72070.0569	78809.2561	85843.5337	93171.8433	100793.174	108706.351																							

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'-J'-N+2 (IN GHZ) ARE:

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53		
ERL:	383.121551	689.560832	995.900752	1302.09715	1608.10587	1913.88275	2219.38364	2524.56436	2829.38076	3133.78868																			
	3437.74396	3741.20244	4044.11996	4346.45236	4648.19548	4949.18516	5249.49724	5549.0756	5847.79196	6145.68628																			
	6442.68637	6738.74805	7033.82717	7327.87957	7620.86109	7912.72757	8203.43485																						

THE PARAMETERS ARE AS FOLLOWS ACCORDING TO
ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE (REF. 5),
FOR $V_1 = V_2 = 1$:

S0 = 2.6279031 GMZ/
S1 = 0.00015105555 GMZ/
S2 = 0 GMZ/

LAM0 = 59.75013584 GMZ/
LAM1 = 0 GMZ/

MU0 = 0.2689138348 GMZ/
MU1 = 0 GMZ/

IN UNITS OF INVERSE CM, THE ABOVE PARAMETERS ARE:
1.21914 0.0002E-6 0 1.99305 0 -0.00897 0

K = 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

I(K,K+1)K(K)

2.05052694 6.709147694 10.80196626 14.84982434 18.87902487 22.89872258 26.91289212 30.92357824 34.93192463
38.93862361 42.94411885 46.94870781 50.95259738 54.95593594 58.95883244 62.9613446 66.96340978 70.96560223
74.96738578 78.96899154 82.9704472 86.97176598 90.97297243 94.97407832 98.97509564 102.9760346 106.9769037
I(K,K+1)K(K)
2 6.534738507 10.73463631 14.81412516 18.8569198 22.88367863 26.90199576 30.91532223 34.92545307 38.9334144
42.93983356 46.94512371 50.94955421 54.95331984 58.95655962 62.95937634 66.96184763 70.96403322 74.96597981
78.96772446 82.96929693 86.9707214 90.97201775 94.97320242 98.97428917 102.9752896 106.9762135

I(K,K+2)K(K+1)

0.0494730599 0.04085230595 0.0313670688 0.02517565708 0.02096513066 0.01794408389 0.01567930775 0.0139217588
0.01251981759 0.01137639303 0.01042660661 0.009625526731 0.008941081205 0.008349779073 0.007834028313 0.007380397827
0.006978498373 0.006619989776 0.006298426385 0.006008461358 0.005745759202 0.005506743555 0.005288438234
0.005086346572 0.00490435873 0.004734679685 0.004577772729

I(K,K+1)K(K+2)K(K+1)

0.041168877 0.2192673234 0.181019537 0.1152928698 0.09328653298 0.07836553065 0.06758266681 0.05942734524
0.05304488924 0.04791511549 0.0437042297 0.04018461288 0.03720161578 0.034464152114 0.03242107516 0.03047754256
0.02876275174 0.02723910034 0.02587680726 0.02465197984 0.02354522724 0.0225406441 0.02162507967 0.02078733279
0.0200187613 0.01931092992 0.01865735523

I(K,K+1)K(K+2)K(K+1)

0.13192816 0.04536368952 0.04301769435 0.03196908835 0.02541277959 0.02108116149 0.01801110224 0.015723339818
0.01395397426 0.01254539582 0.01138802959 0.01044578901 0.009643121656 0.008957617396 0.008365591969 0.00784933404
0.007395353288 0.006993162945 0.006634517052 0.006312829945 0.006022781058 0.0057600253 0.00552047944 0.00530244214
0.005102574108 0.004918601759 0.00474894845

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REFNO = 5

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE SUBMILLIMETER TRANSITIONS OF C16=O16 ARE AS FOLLOWS (IN UNITS OF INVERSE CM):

NUF:	12.1311775	23.5757022	34.9224514	46.373412	57.7523122	69.1192944	80.473395	91.813216	103.13716	114.4443527
	125.730561	136.996473	148.239452	159.457674	170.649307	181.81251	192.9454	204.04625	215.11309	226.144109
	237.137455	248.091273	259.003709	269.872908	280.697014	291.474171	302.202522			
NUG:	14.0210227	25.5377415	36.9830915	48.4029048	59.8064963	71.1960099	82.5713768	93.9316594	105.275521	116.601422
	127.907709	139.19266	150.454514	161.691482	172.901755	184.083513	195.234929	206.354165	217.439383	228.488737
	239.500381	250.472467	261.403144	272.290559	283.13286	293.928193	304.674704			
NUM:	16.1083075	27.5528322	38.9595814	50.350542	61.7294422	73.0964244	84.450525	95.790346	107.11429	118.420657
	129.707691	140.973603	152.216582	163.434804	174.626437	185.78964	196.92257	208.02338	219.09022	230.21239
	241.114585	252.068403	262.980839	273.850038	284.674144	295.451301	306.179652			

THE RESPECTIVE LOWER STATE ENERGIES (ALSO IN INVERSE CM) ARE AS FOLLOWS:

ELF:	3.97713	18.1955924	43.7863852	80.7453265	129.066376	188.741634	259.761343	342.113886	435.785788	540.761716
	657.024478	784.555021	923.332437	1073.33396	1234.53495	1404.90894	1590.42758	1785.00066	1990.77612	2207.54005
	2435.31666	2674.06832	2923.75553	3184.33693	3455.76932	3738.00762	4031.0049			
ELG:	2.08728484	16.233553	41.7857451	78.7158337	127.012192	186.664918	257.663361	339.995442	433.647427	538.603821
	654.84733	782.358834	921.117375	1071.10015	1232.28251	1404.63794	1588.13809	1782.75274	1988.44983	2205.19542
	2432.95373	2671.68713	2921.35609	3181.91928	3453.33348	3735.5536	4028.53272			
ELM:	2.08728484	16.233553	41.7857451	78.7158337	127.012192	186.664918	257.663361	339.995442	433.647427	538.603821
	654.84733	782.358834	921.117375	1071.10015	1232.28251	1404.63794	1588.13809	1782.75274	1988.44983	2205.19542
	2432.95373	2671.68713	2921.35609	3181.91928	3453.33348	3735.5536	4028.53272			

THESE SUBMM TRANSITION FREQUENCIES, EXPRESSED IN GIGAHERTZ, ARE:

NUF	(GMZ)	363.683553	706.78177	1048.74751	1390.23992	1731.37076	2072.14432	2412.53169	2752.49097	3091.97426	3430.93062
		3769.3074	4107.05094	4444.10697	4780.42092	5115.93751	5450.60192	5784.35877	6117.15267	6448.9282	6779.62983
NUG	(GMZ)	7109.20204	7437.58925	7764.73584	8090.58625	8415.08479	8738.17582	9059.80369			
		420.339686	765.60223	1108.72519	1451.08258	1792.95365	2134.40268	2475.4276	2816.00031	3156.08073	3495.6227
		3834.57665	4172.89098	4510.51287	4847.38867	5183.44642	5518.6849	5852.99592	6186.34225	6518.66871	6849.92001
NUM	(GMZ)	7180.0408	7508.97566	7836.66509	8163.06559	8488.10961	8811.74556	9133.91785			
		482.914911	826.013128	1167.97887	1509.47128	1850.60212	2191.37567	2531.76305	2871.72233	3211.20562	3550.16144
		3888.53875	4226.2823	4563.33833	4899.65217	5235.16887	5569.83328	5903.59013	6236.34403	6568.15955	6899.6114
		7228.4334	7556.82061	7883.96722	8209.81761	8534.31614	8857.40718	9179.03505			

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REFNO = 5

INPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53

THE MICROWAVE TRANSITION FREQUENCIES (IN GMZ) OF
016-016 ARE AS FOLLOWS:

FM: 56.6561325 58.82046 59.9776816 60.5426626 61.5824925 62.2583648 62.8959113 63.5043366 64.1064699 64.6920826
65.2652485 66.8400372 68.4058933 69.9678557 71.5266906 73.0829759 74.6371552 76.1895748 77.7405093 79.2901789
80.8387624 82.3864063 83.9332322 85.4793414 87.0248193 88.5697382 90.1141599
FM: 119.231358 62.5752253 60.4108978 59.2536763 58.3886953 57.6484354 56.972993 56.3354466 55.7220213 55.124888
54.5392753 53.9621093 53.3913206 52.8254646 52.2635022 51.704672 51.1483819 50.5942027 50.041783 49.4908485
48.9411789 48.3925355 47.8449515 47.2981256 46.7520164 46.2065385 45.6616196

THE RESPECTIVE LOWER STATE ENERGIES (IN GIGAEVOLT)
RELATIVE TO THE GROUND STATE ARE:

ELP: 62.5752253 486.669676 1252.70512 2359.84133 3807.72971 5596.07347 7724.55323 10192.8049 13000.4228 16146.9363
19631.8291 23454.5278 27614.4042 32110.7147 36942.9001 42109.986 47611.1822 53445.5827 59612.2262 66110.0956
72938.118 80995.165 87580.0524 95391.5403 103528.333 111989.079 120772.373
ELM: 0 482.914911 1252.727191 2361.43031 3810.92391 5600.68336 7730.47615 10199.9808 13008.8072 16156.5035 19642.559
23466.4057 27627.4188 32124.9171 36958.1633 42126.3643 47628.6709 53464.1781 59631.925 66130.8949 72960.0156
80118.1588 87604.1407 95416.7215 103554.606 112016.443 120800.825

THE PREDICTED LMR AND RAMAN LINES CONNECTING
STATES N=J WITH STATES N'-J' (IN GMZ) ARE:

ERL: 426.258778 767.192668 1108.00119 1448.62861 1789.01923 2129.11731 2468.84714 2808.21299 3147.09915 3485.4699
3823.26951 4160.44226 4496.9344 4832.68432 5167.64218 5501.7903 5834.95297 6167.19446 6498.41904 6826.57101
7157.59464 7485.4342 7812.03399 8137.33827 8461.29133 8783.83744 9104.92089

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APPENDIX C

ADDITIONAL APL PARAMETER-SETTING PROGRAMS

The parameter-setting program PARAMSTEIN (Fig. 1, p. 8) gave B_0 , B_1 , B_2 , λ_0 , λ_1 , μ_0 , and μ_1 for $^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}^{18}\text{O}$, according to Steinbach and Gordy,⁷ for the vibrational ground state, $v = 0$. These seven parameters (for $^{16}\text{O}^{16}\text{O}$ only) according to Refs. 1 through 6 (for $v = 0$) are contained in the APL program PARAMETERS (Fig. C-1). The APL program containing the parameters for the upper vibrational state, $v = 1$, in $^{16}\text{O}_2$, according to Ref. 5, is PARAMSTEINUPPER (Fig. C-2). In this program, $\Delta G_{1/2}$ is represented as GV.

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V PARAMETERS;X;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1;REFTEXT1;REFTEXT2;REFTEXT3;REFTEXT4;REFTEXT5;
REFTEXT6;REFTEXTX
[1]  * 'REFNO' IS AN INTEGER FROM 1 TO 6, CORRESPONDING TO ONE
[2]  * OF THE SIX REFERENCES LISTED IN 'REFTEXT'.
[3]  VECB0=43.1029 43.100589 43.100518 43.100518,(1.437708=SPEEDOFLIGHT),43.1004608
[4]  VECB1=-0.0001471499 -0.00014 -0.0001449629 -0.00014496,(-4.84E-6=SPEEDOFLIGHT),-0.0001452
[5]  VECB2=0 0 -1.57E-10 -1.7E-10 0 0
[6]  VECLAM0=59.50157 59.501346 59.501342 59.501342,(1.5=1.3239=SPEEDOFLIGHT),59.501342
[7]  VECLAM1=5.678E-5 5.845E-5 5.847E-5 5.847E-5 0 5.847E-5
[8]  VECMU0=-0.25267 -0.2525917 -0.2525865 -0.2525865,(-0.008436=SPEEDOFLIGHT),-0.2525865
[9]  VECMU1=0 -2.455E-7 -2.464E-7 -2.464E-7 0 -2.464E-7
[10] REFTEXT1='TINKHAM AND STRANDBERG'
[11] REFTEXT2='WILHEIT AND BARRETT'
[12] REFTEXT3='WELCH AND MIZUSHIMA'
[13] REFTEXT4='EVENSON AND MIZUSHIMA'
[14] REFTEXT5='ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE'
[15] * BASED ON THEIR TABLES II AND X, AND DO VALUE ON P. 118.
[16] REFTEXT6='TOMUTA, MIZUSHIMA, HOWARD, AND EVENSON'
[17] * BASED ON PRIVATE COMMUNICATION FROM M. MIZUSHIMA TO M. GREENEBAUM, 7/7/75.
[18] 'PLEASE TYPE REFERENCE NUMBER'
[19] X=REFNO-1
[20] B0=VECB0[X]
[21] B1=VECB1[X]
[22] B2=VECB2[X]
[23] LAM0=VECLAM0[X]
[24] LAM1=VECLAM1[X]
[25] MU0=VECMU0[X]
[26] MU1=VECMU1[X]
[27] REFTEXTX=6 420 ' '
[28] REFTEXTX[1;10REFTEXT1]=REFTEXT1
[29] REFTEXTX[2;10REFTEXT2]=REFTEXT2
[30] REFTEXTX[3;10REFTEXT3]=REFTEXT3
[31] REFTEXTX[4;10REFTEXT4]=REFTEXT4
[32] REFTEXTX[5;10REFTEXT5]=REFTEXT5
[33] REFTEXTX[6;10REFTEXT6]=REFTEXT6
[34] '      THANK YOU.

[35] 'THE PARAMETERS ACCORDING TO ';REFTEXTX[X];'
      (REF. ';X;') ARE AS FOLLOWS:

[36] 'B0 = ';B0;' GHZ; '
[37] 'B1 = ';B1;' GHZ; '
[38] 'B2 = ';B2;' GHZ;

[39] 'LAM0 = ';LAM0;' GHZ; '
[40] 'LAM1 = ';LAM1;' GHZ;

[41] 'MU0 = ';MU0;' GHZ; '
[42] 'MU1 = ';MU1;' GHZ.

[43] 'TEMPERATURE IS ASSUMED TO BE 296K;IF THIS IS INCORRECT, WRITE:'
[44] '  'TEMP-( )' WHERE DESIRED NUMBER IS INSERTED.'
[45] TEMP=296
[46] *      REVISED 10 JULY 1975

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Fig. C-1: Listing of APL function PARAMETERS

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V PARAMSTEINUPPER;X;VECB0;VECB1;VECB2;VECLAM0;VECLAM1;VECMU0;VECMU1;REFTEXT5;VECGV
[1]  * 'REFNO' IS 5, CORRESPONDING TO 'REFTEXT5'; 'V' IS 0 OR 1,
[2]  * CORRESPONDING TO V''. (ONLY V'=V'' TRANSITIONS CONSIDERED.)
[3]  VECB0+(1.437708 1.421914)*SPEEDOFLIGHT
[4]  VECB1+(-4.84E-6 -4.8402E-6)*SPEEDOFLIGHT
[5]  VECB2+0 0
[6]  VECLAM0+1.5*(1.3239 1.3287)*SPEEDOFLIGHT
[7]  VECLAM1+0 0
[8]  VECMU0+(-8.436 -8.97)*0.001*SPEEDOFLIGHT
[9]  VECMU1+0 0
[10] VECGV+0 1556.378* INVERSE CM
[11] REFTEXT5+'ALBRITTON, HARROP, SCHMELTEKOPF, AND ZARE (REF. 5),
FOR V'' = V'''' = '
[12] VV+1;REFNO+5
[13] X+VV+1
[14] B0+VECB0[X]
[15] B1+VECB1[X]
[16] B2+VECB2[X]
[17] LAM0+VECLAM0[X]
[18] LAM1+VECLAM1[X]
[19] MU0+VECMU0[X]
[20] MU1+VECMU1[X]
[21] GV+VECGV[X]
[22] 'THE PARAMETERS ARE AS FOLLOWS ACCORDING TO
';REFTEXT5;VV;';
,
[23] 'B0 = ';B0; ' GHZ; '
[24] 'B1 = ';B1; ' GHZ; '
[25] 'B2 = ';B2; ' GHZ;
,
[26] 'LAM0 = ';LAM0; ' GHZ; '
[27] 'LAM1 = ';LAM1; ' GHZ;
,
[28] 'MU0 = ';MU0; ' GHZ; '
[29] 'MU1 = ';MU1; ' GHZ.
,
[30] 'IN UNITS OF INVERSE CM, THE ABOVE PARAMETERS ARE:'
[31] +PARAMVEC+(B0,B1,B2,LAM0,LAM1,MU0,MU1)*SPEEDOFLIGHT
[32] 'TEMPERATURE IS ASSUMED TO BE 296K;IF THIS IS INCORRECT, WRITE:'
[33] ' 'TEMP+( )' WHERE DESIRED NUMBER IS INSERTED.'
[34] TEMP+296
[35] X+1* CALCULATION FOR 016=016 ONLY, FOR V'=V''=1 ONLY.
[36] * THIS IS A MODIFIED FORM OF 'PARAMUPPER' FOR USE WITH 'ABCD' OR
[37] * 'ABCDLP' (THEORY OF W. R. STEINBACH INSTEAD OF TINKHAM AND STRANDBERG)
[38] * VERSION OF 28 JULY 1975.
V

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Fig. C-2: Listing of APL function PARAMSTEINUPPER

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APPENDIX D

Temperature Dependence of Rotational

State Sum for Molecular Oxygen

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$

EMPLOYING THE PARAMETERS OF REF. 1 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64467	55.83416	1.01452
100K	73.32311	72.51190	1.01119
125K	91.45851	90.63987	1.00903
150K	109.59893	108.76785	1.00764
175K	127.74352	126.89582	1.00668
200K	145.89184	145.02380	1.00599
225K	164.04365	163.15177	1.00547
250K	182.19881	181.27975	1.00507
273K	198.90444	197.95748	1.00478
275K	200.35724	199.40772	1.00476
296K	215.61279	214.63522	1.00455
300K	218.51886	217.53570	1.00452
325K	236.68364	235.66367	1.00433

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$

EMPLOYING THE PARAMETERS OF REF. 2 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64683	55.83716	1.01450
100K	73.32569	72.51579	1.01117
125K	91.46140	90.64473	1.00901
150K	109.60200	108.77368	1.00762
175K	127.74661	126.90263	1.00665
200K	145.89481	145.03157	1.00595
225K	164.04635	163.16052	1.00543
250K	182.20110	181.28947	1.00503
273K	198.90622	197.96810	1.00474
275K	200.35896	199.41841	1.00472
296K	215.61392	214.64673	1.00451
300K	218.51987	217.54736	1.00447
325K	236.68380	235.67631	1.00427

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ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 3 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64740	55.83725	1.01451
100K	73.32662	72.51591	1.01118
125K	91.46282	90.64488	1.00902
150K	109.60401	108.77386	1.00763
175K	127.74932	126.90284	1.00667
200K	145.89832	145.03181	1.00597
225K	164.05077	163.16079	1.00545
250K	182.20653	181.28976	1.00506
273K	198.91267	197.96842	1.00477
275K	200.36551	199.41874	1.00475
296K	215.62149	214.64708	1.00454
300K	218.52765	217.54772	1.00450
325K	236.69291	235.67669	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 4 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64740	55.83725	1.01451
100K	73.32662	72.51591	1.01118
125K	91.46282	90.64488	1.00902
150K	109.60401	108.77386	1.00763
175K	127.74932	126.90284	1.00667
200K	145.89832	145.03181	1.00597
225K	164.05077	163.16079	1.00545
250K	182.20653	181.28976	1.00506
273K	198.91268	197.96842	1.00477
275K	200.36551	199.41874	1.00475
296K	215.62150	214.64708	1.00454
300K	218.52765	217.54772	1.00450
325K	236.69291	235.67669	1.00431

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ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 5 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64484	55.83610	1.01448
100K	73.32372	72.51442	1.01116
125K	91.45955	90.64302	1.00901
150K	109.60038	108.77163	1.00762
175K	127.74532	126.90023	1.00666
200K	145.89396	145.02884	1.00597
225K	164.04605	163.15744	1.00545
250K	182.20144	181.28605	1.00505
273K	198.90725	197.96436	1.00476
275K	200.36006	199.41465	1.00474
296K	215.61574	214.64268	1.00453
300K	218.52183	217.54326	1.00450
325K	236.68672	235.67186	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 6 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64749	55.83732	1.01451
100K	73.32675	72.51600	1.01118
125K	91.46299	90.64500	1.00902
150K	109.60423	108.77400	1.00763
175K	127.74958	126.90300	1.00667
200K	145.89863	145.03200	1.00598
225K	164.05114	163.16100	1.00546
250K	182.20695	181.29001	1.00506
273K	198.91315	197.96869	1.00477
275K	200.36599	199.41901	1.00475
296K	215.62202	214.64737	1.00454
300K	218.52818	217.54801	1.00451
325K	236.69350	235.67701	1.00431

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ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 7 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	56.64748	55.83732	1.01451
100K	73.32672	72.1600	1.01118
125K	91.46295	90.64500	1.00902
150K	109.60416	108.77401	1.00763
175K	127.74949	126.90301	1.00667
200K	145.89851	145.03201	1.00597
225K	164.05098	163.16101	1.00545
250K	182.20676	181.29001	1.00506
273K	198.91292	197.96869	1.00477
275K	200.36575	199.41901	1.00475
296K	215.62175	214.64737	1.00454
300K	218.52791	217.54801	1.00450
325K	236.69317	235.67701	1.00431

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{18}$
EMPLOYING THE PARAMETERS OF REF. 7 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	116.28488	118.23962	0.98347
100K	151.60712	153.55795	0.98730
125K	190.01360	191.94744	0.98993
150K	228.42996	230.33693	0.99172
175K	266.85466	268.72642	0.99303
200K	305.28693	307.11590	0.99404
225K	343.72634	345.50539	0.99485
250K	382.17263	383.89488	0.99551
273K	417.54915	419.21321	0.99603
275K	420.62564	422.28437	0.99607
296K	452.93128	454.53154	0.99648
300K	459.08526	460.67386	0.99655
325K	497.55143	499.06334	0.99697

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ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{18}=O_{18}$
EMPLOYING THE PARAMETERS OF REF. 7 ($V = 0$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	63.28076	62.81336	1.00744
100K	82.04495	81.57580	1.00575
125K	102.44779	101.96975	1.00469
150K	122.85599	122.36370	1.00402
175K	143.26871	142.75765	1.00358
200K	163.68549	163.15160	1.00327
225K	184.10612	183.54555	1.00305
250K	204.53043	203.93950	1.00290
273K	223.32398	222.70193	1.00279
275K	224.95834	224.33344	1.00279
296K	242.12053	241.46436	1.00272
300K	245.38980	244.72739	1.00271
325K	265.82476	265.12134	1.00265

ROTATIONAL PARTITION FUNCTION FOR MOLECULAR OXYGEN, $O_{16}=O_{16}$
EMPLOYING THE PARAMETERS OF REF. 5 ($V = 1$)

TEMP	EXACT SUM	CLASSICAL	RATIO
77K	57.22604	56.45631	1.01363
100K	74.09050	73.31988	1.01051
125K	92.42815	91.64985	1.00849
150K	110.77088	109.97982	1.00719
175K	129.11783	128.30979	1.00630
200K	147.46858	146.63976	1.00565
225K	165.82288	164.96973	1.00517
250K	184.18059	183.29969	1.00481
273K	201.07261	200.16327	1.00454
275K	202.54161	201.62966	1.00452
296K	217.96740	217.02684	1.00433
300K	220.90590	219.95963	1.00430
325K	239.27341	238.28960	1.00413

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APPENDIX E

Comparison of $^{16}\text{O}^{16}\text{O}$ ($v = 0$) Line Strengths Computed by Us at 273 and 296K with Theoretical Results Given in Ref. 8

See text, pp. 27 and 34 for discussion of this Appendix, which was computed using the APL program GBBSTRENGTH. It is assumed that the cm-atm quoted in Ref. 8 refers to 273K and 1 atm, so that $1 \text{ (cm-atm)}_{\text{STP}} = 2.686754(84) \text{ E19 molecule cm}^{-2}$ (Loschmidt's constant, L_0).^{13,23}

NOTE ADDED IN PROOF: The factor L_0 used in the APL program GBBSTRENGTH should have been replaced by $L_0/0.99519$ in computing the integrated line strength in units of cm^{-1} per $(\text{cm-atm})_{\text{STP}}$ (see p. 17 of text). The 0.5% change in our computed line strengths does not affect the conclusions to be drawn from the comparison, i. e., that the results of Ref. 8 may be in error by as much as a factor of 2. Note also that the APL program GBBSTRENGTH was used only in generating this Appendix; the line strengths elsewhere in this report, given in units of cm^{-1} per molecule cm^{-2} , have been calculated correctly.

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TEMP = 273K) KT = 189.7 INVERSE CM) X = 1
 REFNO = 7
 NINPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
 39 41 43 45 47 49 51 53

THE LINE STRENGTHS OF THE SUBMILLIMETER TRANSITIONS OF O16=O16, IN
 UNITS OF 1.0E=6 INVERSE CM PER CM-ATM (AT STP), ARE AS FOLLOWS:

SF: 0.6996 1.959 2.803 3.152 3.057 2.65 2.09 1.514 1.015 0.6316
 0.3661 0.1981 0.1002 0.04744 0.02105 0.008763 0.003424 0.001257
 0.0004336 0.0001406 4.293E=5 1.233E=5 3.338E=6 8.5E=7 2.041E=7
 4.622E=8 9.868E=9

SG: 7.636 12.37 15.14 15.79 14.68 12.33 9.529 6.801 4.504 2.777
 1.597 0.8586 0.432 0.2036 0.09 0.03733 0.01454 0.005324 0.001832
 0.0005931 0.0001807 5.181E=5 1.399E=5 3.561E=6 8.541E=7 1.931E=7
 4.12E=8

SH: 3.26 4.261 4.754 4.71 4.228 3.479 2.643 1.862 1.221 0.7465
 0.4264 0.2279 0.1141 0.05357 0.02359 0.009757 0.00379 0.001384
 0.0004752 0.0001535 4.668E=5 1.337E=5 3.604E=6 9.159E=7 2.194E=7
 4.956E=8 1.056E=8

GEBBIE, BURROUGHS, AND BIRD, PROC. ROY. SOC. (LONDON) A, VOL. 310, PP.
 579 TO 590 (1969) GIVE FOR THE FIRST SEVERAL LINES (IN THE SAME UNITS):

SF: 0.62 1.5 1.8 1.8 1.4
 SG: 5.7 8.7 9.5 8.3 6.3
 SH: 2.1 2.9 2.9 2.4 1.8

RATIOS OF OUR RESULTS FOR K = 1 THROUGH 9 TO THOSE OF GEBBIE, ET AL:

F: 1.128 1.306 1.557 1.751 2.183
 G: 1.34 1.422 1.593 1.902 2.325
 H: 1.553 1.469 1.639 1.962 2.349

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TEMP = 296KJ KT = 205.7 INVERSE CMJ X = 1
 REFNO = 7
 NINPUT: 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37
 39 41 43 45 47 49 51 53

THE LINE STRENGTHS OF THE SUBMILLIMETER TRANSITIONS OF O₁₆=O₁₆, IN
 UNITS OF 1.0E-6 INVERSE CM PER CM-ATM (AT STP), ARE AS FOLLOWS:

SF: 0.5977 1.687 2.446 2.799 2.775 2.471 2.061 1.511 1.055 0.686E
 0.4185 0.2391 0.1283 0.06477 0.03078 0.01278 0.00582 0.002319
 0.0008725 0.0003101 0.0001041 3.307E-5 9.933E-6 2.823E-6 7.596E-7
 1.935E-7 4.671E-8

SG: 6.521 10.65 13.2 14.01 13.29 11.5 9.165 6.781 4.678 3.018 1.825
 1.036 0.553 0.2778 0.1315 0.05869 0.02471 0.009818 0.003685
 0.001307 0.000438 0.0001389 4.165E-5 1.182E-5 3.176E-6 8.083E-7
 1.949E-7

SH: 2.786 3.67 4.148 4.182 3.838 3.244 2.543 1.857 1.268 0.8115
 0.4874 0.2751 0.1461 0.07312 0.03449 0.01834 0.00644 0.002553
 0.0009559 0.0003383 0.0001132 3.583E-5 1.073E-5 3.041E-6 8.16E-7
 2.074E-7 4.995E-8

GEBBIE, BURROUGHS, AND BIRD, PROC. ROY. SOC. (LONDON) A, VOL. 310, PP.
 579 TO 590 (1969) GIVE FOR THE FIRST SEVERAL LINES (IN THE SAME UNITS):

SF: 0.62 1.5 1.8 1.8 1.4
 SG: 5.7 8.7 9.5 8.3 6.3
 SH: 2.1 2.9 2.9 2.4 1.8

RATIOS OF OUR RESULTS FOR K = 1 THROUGH 9 TO THOSE OF GEBBIE, ET AL:

F: 0.964 1.125 1.359 1.555 1.982
 G: 1.144 1.224 1.39 1.688 2.11
 H: 1.326 1.266 1.43 1.742 2.132

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APPENDIX F

RRI Absorption Line Parameters

for Molecular Oxygen Isotopes

$^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}^{18}\text{O}$ (AFCRL Format)

In the following eight file listings, the contents are labelled at the top of each page with the file names as well as brief descriptions of the contents. The units are as follows:

FREQ: Transition frequency: (cm^{-1})
STRENGTH: Line strength at 296K: $(\text{cm}^{-1}/\text{molecule cm}^{-2})$
WIDTH: Line half-width at half-maximum: $(\text{cm}^{-1} \text{ atm}^{-1})$
E'': Energy of lower state of the transition, with respect to the ground state, including $\Delta G_{1/2}$: (cm^{-1})

The sequence of the eight file listings is as follows:

AF760K15V0: Microwave fine structure lines of $^{16}\text{O}^{16}\text{O}$, $v = 0$.
AF7K15V0: Submillimeter rotational lines of $^{16}\text{O}^{16}\text{O}$, $v = 0$.
AF760K25V0: Microwave fine structure lines of $^{16}\text{O}^{18}\text{O}$, $v = 0$.
AF7K25V0: Submillimeter rotational lines of $^{16}\text{O}^{18}\text{O}$, $v = 1$.
AF760K35V0: Microwave fine structure lines of $^{18}\text{O}^{18}\text{O}$, $v = 0$.
AF7K35V0: Submillimeter rotational lines of $^{18}\text{O}^{18}\text{O}$, $v = 0$.
AF560K15V1: Microwave fine structure lines of $^{16}\text{O}^{16}\text{O}$, $v = 1$.
AF5K15V1: Submillimeter rotational lines of $^{16}\text{O}^{16}\text{O}$, $v = 1$.

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RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCLRL FORMAT)
 AF760K15V0 BU, B1, ETC.: REF: 7, 016-016 MICROWAVE LINES, KHUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E11	V1	J1	K1	V11	J11	K11	ID	DATE	ISO	MC
1	1.54817	2.06E+33	.032	4074.552	0	53	53	0	52	53	53	75	66	7
2	1.56499	8.55E+33	.032	3778.223	0	51	51	0	50	51	51	75	66	7
3	1.58183	3.36E+32	.032	3492.781	0	49	49	0	48	49	49	75	66	7
4	1.59871	1.25E+31	.032	3218.270	0	47	47	0	46	47	47	75	66	7
5	1.61561	4.41E+31	.032	2954.737	0	45	45	0	44	45	45	75	66	7
6	1.63255	1.47E+30	.032	2702.225	0	43	43	0	42	43	43	75	66	7
7	1.64953	4.62E+30	.032	2460.774	0	41	41	0	40	41	41	75	66	7
8	1.66655	1.38E+29	.032	2230.425	0	39	39	0	38	39	39	75	66	7
9	1.68362	3.87E+29	.032	2011.215	0	37	37	0	36	37	37	75	66	7
10	1.70076	1.03E+28	.032	1803.180	0	35	35	0	34	35	35	75	66	7
11	1.71796	2.58E+28	.032	1606.353	0	33	33	0	32	33	33	75	66	7
12	1.73524	6.09E+28	.032	1420.767	0	31	31	0	30	31	31	75	66	7
13	1.75262	1.36E+27	.032	1246.452	0	29	29	0	28	29	29	75	66	7
14	1.77012	2.85E+27	.032	1083.436	0	27	27	0	26	27	27	75	66	7
15	1.78776	5.63E+27	.032	931.745	0	25	25	0	24	25	25	75	66	7
16	1.80558	1.05E+26	.038	791.405	0	23	23	0	22	23	23	75	66	7
17	1.82363	1.83E+26	.035	662.437	0	21	21	0	20	21	21	75	66	7
18	1.84199	3.00E+26	.037	544.863	0	19	19	0	18	19	19	75	66	7
19	1.86075	4.60E+26	.038	438.702	0	17	17	0	16	17	17	75	66	7
20	1.87879	2.74E+26	.045	2.084	0	1	1	0	2	1	1	75	66	7
21	1.88008	6.58E+26	.038	343.970	0	15	15	0	14	15	15	75	66	7
22	1.90026	8.77E+26	.039	260.683	0	13	13	0	12	13	13	75	66	7
23	1.92175	1.08E+25	.041	188.853	0	11	11	0	10	11	11	75	66	7
24	1.94548	1.22E+25	.043	128.492	0	9	9	0	8	9	9	75	66	7
25	1.94957	7.55E+26	.044	16.388	0	3	3	0	4	3	3	75	66	7
26	1.97351	1.26E+25	.044	79.607	0	7	7	0	6	7	7	75	66	7
27	1.98774	1.11E+25	.042	42.224	0	5	5	0	6	5	5	75	66	7
28	2.01159	1.13E+25	.044	42.200	0	5	5	0	4	5	5	75	66	7
29	2.01589	1.31E+25	.041	79.565	0	7	7	0	8	7	7	75	66	7
30	2.03976	1.35E+25	.040	128.398	0	9	9	0	10	9	9	75	66	7
31	2.06143	1.25E+25	.039	188.714	0	11	11	0	12	11	11	75	66	7
32	2.08181	1.05E+25	.038	260.501	0	13	13	0	14	13	13	75	66	7
33	2.08432	8.41E+26	.047	16.253	0	3	3	0	2	3	3	75	66	7
34	2.10139	8.23E+26	.034	343.748	0	15	15	0	16	15	15	75	66	7
35	2.12042	5.97E+26	.036	438.442	0	17	17	0	18	17	17	75	66	7
36	2.13907	4.04E+26	.035	544.866	0	19	19	0	20	19	19	75	66	7
37	2.15746	2.56E+26	.035	662.103	0	21	21	0	22	21	21	75	66	7
38	2.17564	1.52E+26	.032	791.034	0	23	23	0	24	23	23	75	66	7
39	2.19368	8.49E+27	.032	931.339	0	25	25	0	26	25	25	75	66	7
40	2.21160	4.45E+27	.032	1082.994	0	27	27	0	28	27	27	75	66	7
41	2.22943	2.20E+27	.032	1245.975	0	29	29	0	30	29	29	75	66	7
42	2.24720	1.02E+27	.032	1420.855	0	31	31	0	32	31	31	75	66	7
43	2.26492	4.48E+28	.032	1605.806	0	33	33	0	34	33	33	75	66	7
44	2.28260	1.85E+28	.032	1802.598	0	35	35	0	36	35	35	75	66	7
45	2.30026	7.24E+29	.032	2010.599	0	37	37	0	38	37	37	75	66	7
46	2.31789	2.67E+29	.032	2229.774	0	39	39	0	40	39	39	75	66	7
47	2.33551	9.29E+30	.032	2460.088	0	41	41	0	42	41	41	75	66	7

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RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCHL FORMAT)
 AF76CK15V0 B0, B1, ETC. I REF. 7, 016*016 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	NO
48	2.35312	3.06E+30	.032	2701.504	0	43 43	0	44 43 43+		75	66	7
49	2.37072	9.51E+31	.032	2953.982	0	45 45	0	46 45 45+		75	66	7
50	2.38833	2.80E+31	.032	3217.481	0	47 47	0	48 47 47+		75	66	7
51	2.40594	7.80E+32	.032	3491.957	0	49 49	0	50 49 49+		75	66	7
52	2.42355	2.06E+32	.032	3777.365	0	51 51	0	52 51 51+		75	66	7
53	2.44118	5.13E+33	.032	4073.659	0	53 53	0	54 53 53+		75	66	7
54	3.96108	1.00E+21	.050	0.000	0	1 1	0	0 1 1+		75	66	7

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HRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF7K15V0 BC, B1, ETC.: REF. 7, O16+O16 SUMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
1	12.29178	2.22E-26	.048	3.961	0	2 3	0	1 1	SF	75	66	7
2	14.16858	2.43E-25	.045	2.084	0	2 3	0	2 1	SG	75	66	7
3	16.25289	1.04E-25	.045	2.084	0	3 3	0	2 1	SM	75	66	7
4	23.86295	6.28E-26	.045	18.337	0	4 8	0	3 3	SF	75	66	7
5	25.81252	3.96E-25	.044	16.388	0	4 5	0	4 3	SG	75	66	7
6	27.82411	1.37E-25	.044	16.388	0	5 5	0	4 3	SM	75	66	7
7	35.39530	9.10E-26	.043	44.212	0	6 7	0	5 5	SF	75	66	7
8	37.38305	4.91E-25	.042	42.224	0	6 7	0	6 5	SG	75	66	7
9	39.35655	1.54E-25	.042	42.224	0	7 7	0	6 5	SM	75	66	7
10	46.91156	1.04E-26	.042	81.581	0	8 9	0	7 7	SF	75	66	7
11	48.92745	5.22E-25	.041	79.565	0	8 9	0	8 7	SG	75	66	7
12	50.87292	1.56E-25	.041	79.565	0	9 9	0	8 7	SM	75	66	7
13	58.41563	1.03E-25	.041	130.438	0	10 11	0	9 9	SF	75	66	7
14	60.45539	4.95E-25	.040	128.398	0	10 11	0	10 9	SG	75	66	7
15	62.37713	1.43E-25	.040	128.398	0	11 11	0	10 9	SM	75	66	7
16	69.90770	9.19E-26	.041	190.775	0	12 13	0	11 11	SF	75	66	7
17	71.96913	4.28E-25	.039	188.714	0	12 13	0	12 11	SG	75	66	7
18	73.86939	1.21E-25	.039	188.714	0	13 13	0	12 11	SM	75	66	7
19	81.38685	7.48E-26	.038	262.583	0	14 15	0	13 13	SF	75	66	7
20	83.46666	3.41E-25	.038	260.501	0	14 15	0	14 13	SG	75	66	7
21	85.34874	9.46E-26	.038	260.801	0	15 15	0	14 13	SM	75	66	7
22	92.85169	5.62E-26	.036	345.850	0	16 17	0	15 15	SF	75	66	7
23	94.95307	2.52E-25	.034	343.748	0	16 17	0	16 15	SG	75	66	7
24	96.81382	6.91E-26	.034	343.748	0	17 17	0	16 15	SM	75	66	7
25	104.30063	3.92E-26	.037	440.562	0	18 19	0	17 17	SF	75	66	7
26	106.42105	1.74E-25	.036	438.442	0	18 19	0	18 17	SG	75	66	7
27	108.26304	4.72E-26	.036	438.442	0	19 19	0	18 17	SM	75	66	7
28	115.73199	2.56E-26	.036	544.705	0	20 21	0	19 19	SF	75	66	7
29	117.87106	1.12E-25	.035	544.566	0	20 21	0	20 19	SG	75	66	7
30	119.69469	3.02E-26	.035	544.566	0	21 21	0	20 19	SM	75	66	7
31	127.14400	1.56E-26	.035	664.261	0	22 23	0	21 21	SF	75	66	7
32	129.30146	6.79E-26	.035	662.103	0	22 23	0	22 21	SG	75	66	7
33	131.10704	1.81E-26	.035	662.103	0	23 23	0	22 21	SM	75	66	7
34	138.53489	8.90E-27	.035	793.210	0	24 28	0	23 23	SF	75	66	7
35	140.71053	3.86E-26	.032	791.034	0	24 28	0	24 23	SG	75	66	7
36	142.49829	1.02E-26	.032	791.034	0	25 28	0	24 23	SM	75	66	7
37	149.90225	4.78E-27	.032	933.533	0	26 27	0	25 25	SF	75	66	7
38	152.09653	2.06E-26	.032	931.339	0	26 27	0	26 25	SG	75	66	7
39	153.86664	5.44E-27	.032	931.339	0	27 27	0	26 25	SM	75	66	7
40	161.24605	2.41E-27	.032	1085.206	0	28 29	0	27 27	SF	75	66	7
41	163.45765	1.03E-26	.032	1082.994	0	28 29	0	28 27	SG	75	66	7
42	165.21027	2.72E-27	.032	1082.994	0	29 29	0	28 27	SM	75	66	7
43	172.56267	1.15E-27	.032	1248.204	0	30 31	0	29 29	SF	75	66	7
44	174.79210	4.89E-27	.032	1245.975	0	30 31	0	30 29	SG	75	66	7
45	176.52734	1.28E-27	.032	1245.975	0	31 31	0	30 29	SM	75	66	7
46	183.85086	5.13E-28	.032	1422.802	0	32 33	0	31 31	SF	75	66	7
47	186.09807	2.18E-27	.032	1420.255	0	32 33	0	32 31	SG	75	66	7

RIVERSIDE RESEARCH INSTITUTE

NRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

4F7K15VC B0, B1, ETC.: REF. 7, O16=O16 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
48	167.81602	5.71E-28	.032	1420.255	0	33 33	0	32 31	SM	75	66	7
49	195.10679	2.17E-28	.032	1638.071	0	34 35	0	33 33	SF	75	66	7
50	197.37371	9.19E-28	.032	1605.806	0	34 35	0	34 33	SO	75	66	7
51	199.07447	2.40E-28	.032	1605.804	0	35 35	0	34 33	SM	75	66	7
52	206.33461	8.63E-29	.032	1804.881	0	36 37	0	35 35	SF	75	66	7
53	208.61722	3.65E-28	.032	1802.598	0	36 37	0	36 35	SO	75	66	7
54	210.30084	9.50E-29	.032	1802.598	0	37 37	0	36 35	SM	75	66	7
55	217.52647	3.25E-29	.032	2012.899	0	38 39	0	37 37	SF	75	66	7
56	219.82673	1.37E-28	.032	2010.599	0	38 39	0	38 37	SO	75	66	7
57	221.49328	3.56E-29	.032	2010.599	0	39 39	0	38 37	SM	75	66	7
58	228.68253	1.15E-29	.032	2232.092	0	40 41	0	39 39	SF	75	66	7
59	231.00042	4.86E-29	.032	2229.774	0	40 41	0	40 39	SO	75	66	7
60	232.64995	1.26E-29	.032	2229.774	0	41 41	0	40 39	SM	75	66	7
61	239.80093	3.88E-30	.032	2462.424	0	42 43	0	41 41	SF	75	66	7
62	242.13644	1.63E-29	.032	2460.088	0	42 43	0	42 41	SO	75	66	7
63	243.76899	4.21E-30	.032	2460.088	0	43 43	0	42 41	SM	75	66	7
64	250.87982	1.23E-30	.032	2703.857	0	44 45	0	43 43	SF	75	66	7
65	253.23294	5.17E-30	.032	2701.504	0	44 45	0	44 43	SO	75	66	7
66	254.64855	1.33E-30	.032	2701.504	0	45 45	0	44 43	SM	75	66	7
67	261.91735	3.70E-31	.032	2956.353	0	46 47	0	45 45	SF	75	66	7
68	264.28807	1.55E-30	.032	2953.982	0	46 47	0	46 45	SO	75	66	7
69	265.88678	3.99E-31	.032	2953.982	0	47 47	0	46 45	SM	75	66	7
70	272.91166	1.05E-31	.032	3219.869	0	48 49	0	47 47	SF	75	66	7
71	275.29999	4.40E-31	.032	3217.481	0	48 49	0	48 47	SO	75	66	7
72	276.88182	1.13E-31	.032	3217.481	0	49 49	0	48 47	SM	75	66	7
73	283.86090	2.83E-32	.032	3494.362	0	50 51	0	49 49	SF	75	66	7
74	286.26684	1.18E-31	.032	3491.957	0	50 51	0	50 49	SO	75	66	7
75	287.83183	3.04E-32	.032	3491.957	0	51 51	0	50 49	SM	75	66	7
76	294.76322	7.20E-33	.032	3779.788	0	52 53	0	51 51	SF	75	66	7
77	297.18677	3.01E-32	.032	3777.365	0	52 53	0	52 51	SO	75	66	7
78	298.73494	7.72E-33	.032	3777.365	0	53 53	0	52 51	SM	75	66	7
79	305.61676	1.74E-33	.032	4076.100	0	54 55	0	53 53	SF	75	66	7
80	308.05794	7.25E-33	.032	4073.659	0	54 55	0	54 53	SO	75	66	7
81	309.58931	1.86E-33	.032	4073.659	0	55 55	0	54 53	SM	75	66	7

RIVERSIDE RESEARCH INSTITUTE

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF76CK25V0 B0, B1, ETC.: REF. 7, 016#018 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	IC	DATE	ISO	NO
1	0.00000	0.00E0	.050	0.000	0	0 0	0	1 0 0+		75	68	7
2	0.00000	0.00E0	.050	0.000	0	0 0	0	-1 0 0-		75	68	7
3	1.68274	4.96E-32	.032	2107.907	0	39 39	0	38 39 39-		75	68	7
4	1.69084	8.12E-32	.032	2003.007	0	38 38	0	37 38 38-		75	68	7
5	1.69895	1.31E-31	.032	1900.747	0	37 37	0	36 37 37-		75	68	7
6	1.70707	2.09E-31	.032	1801.129	0	36 36	0	35 36 36-		75	68	7
7	1.71520	3.29E-31	.032	1704.159	0	35 35	0	34 35 35-		75	68	7
8	1.72335	5.11E-31	.032	1609.839	0	34 34	0	33 34 34-		75	68	7
9	1.73150	7.82E-31	.032	1518.173	0	33 33	0	32 33 33-		75	68	7
10	1.73968	1.18E-30	.032	1429.165	0	32 32	0	31 32 32-		75	68	7
11	1.74787	1.76E-30	.032	1342.818	0	31 31	0	30 31 31-		75	68	7
12	1.75608	2.58E-30	.032	1259.136	0	30 30	0	29 30 30-		75	68	7
13	1.76431	3.73E-30	.032	1178.121	0	29 29	0	28 29 29-		75	68	7
14	1.77256	5.33E-30	.032	1099.777	0	28 28	0	27 28 28-		75	68	7
15	1.78084	7.49E-30	.032	1024.107	0	27 27	0	26 27 27-		75	68	7
16	1.78914	1.04E-29	.032	951.113	0	26 26	0	25 26 26-		75	68	7
17	1.79748	1.42E-29	.032	880.799	0	25 25	0	24 25 25-		75	68	7
18	1.80586	1.91E-29	.035	813.167	0	24 24	0	23 24 24-		75	68	7
19	1.81428	2.54E-29	.038	748.219	0	23 23	0	22 23 23-		75	68	7
20	1.82275	3.32E-29	.037	685.959	0	22 22	0	21 22 22-		75	68	7
21	1.83127	4.28E-29	.035	626.388	0	21 21	0	20 21 21-		75	68	7
22	1.83986	5.43E-29	.036	569.509	0	20 20	0	19 20 20-		75	68	7
23	1.84852	6.78E-29	.037	515.324	0	19 19	0	18 19 19-		75	68	7
24	1.85727	8.34E-29	.038	463.835	0	18 18	0	17 18 18-		75	68	7
25	1.86611	1.01E-28	.038	415.043	0	17 17	0	16 17 17-		75	68	7
26	1.87509	1.20E-28	.038	368.952	0	16 16	0	15 16 16-		75	68	7
27	1.88420	1.41E-28	.038	325.562	0	15 15	0	14 15 15-		75	68	7
28	1.89204	5.40E-29	.045	2.633	0	1 1	0	2 1 1+		75	68	7
29	1.89350	1.62E-28	.039	284.875	0	14 14	0	13 14 14-		75	68	7
30	1.90302	1.83E-28	.039	246.893	0	13 13	0	12 13 13-		75	68	7
31	1.91282	2.03E-28	.040	211.617	0	12 12	0	11 12 12-		75	68	7
32	1.92298	2.21E-28	.041	179.048	0	11 11	0	10 11 11-		75	68	7
33	1.93133	1.03E-28	.047	8.025	0	2 2	0	3 2 2+		75	68	7
34	1.93361	2.36E-28	.042	149.187	0	10 10	0	9 10 10-		75	68	7
35	1.94488	2.46E-28	.043	122.036	0	9 9	0	8 9 9-		75	68	7
36	1.95657	1.48E-28	.044	16.146	0	3 3	0	4 3 3+		75	68	7
37	1.95708	2.50E-28	.044	97.595	0	8 8	0	7 8 8-		75	68	7
38	1.97052	2.48E-28	.044	75.865	0	7 7	0	6 7 7-		75	68	7
39	1.97549	1.87E-28	.043	26.989	0	4 4	0	5 4 4+		75	68	7
40	1.98602	2.39E-28	.044	56.845	0	6 6	0	5 6 6-		75	68	7
41	1.99103	2.19E-28	.042	40.850	0	5 5	0	6 5 5+		75	68	7
42	2.00455	2.44E-28	.041	56.827	0	6 6	0	7 6 6-		75	68	7
43	2.00491	2.21E-28	.044	40.836	0	5 5	0	4 5 5+		75	68	7
44	2.01677	2.61E-28	.041	75.819	0	7 7	0	8 7 7-		75	68	7
45	2.02811	2.69E-28	.041	97.824	0	8 8	0	9 8 8-		75	68	7
46	2.03011	1.95E-28	.045	26.934	0	4 4	0	3 4 4+		75	68	7
47	2.03881	2.71E-28	.040	121.942	0	9 9	0	10 9 9-		75	68	7

RIVERSIDE RESEARCH INSTITUTE

NRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)
 AF760K25V0 B0, B1, ETC.: REF. 7, 016-018 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
48	2.04904	2.65E-28	.039	149.072	0	10 10	0	11 10 10+		75	68	7
49	2.05892	2.54E-28	.039	178.912	0	11 11	0	12 11 11+		75	68	7
50	2.06853	2.38E-28	.039	211.461	0	12 12	0	13 12 12+		75	68	7
51	2.06938	1.61E-28	.047	16.033	0	3 3	0	2 3 3-		75	68	7
52	2.07792	2.18E-28	.038	246.718	0	13 13	0	14 13 13+		75	68	7
53	2.08715	1.97E-28	.036	284.681	0	14 14	0	15 14 14+		75	68	7
54	2.09623	1.74E-28	.034	325.350	0	15 15	0	16 15 15+		75	68	7
55	2.10519	1.52E-28	.035	368.722	0	16 16	0	17 16 16+		75	68	7
56	2.11406	1.30E-28	.036	414.795	0	17 17	0	18 17 17+		75	68	7
57	2.12285	1.09E-28	.036	463.569	0	18 18	0	19 18 18+		75	68	7
58	2.13158	9.03E-29	.035	515.041	0	19 19	0	20 19 19+		75	68	7
59	2.14024	7.35E-29	.035	569.208	0	20 20	0	21 20 20+		75	68	7
60	2.14886	5.90E-29	.035	626.070	0	21 21	0	22 21 21+		75	68	7
61	2.15239	1.18E-28	.048	7.804	0	2 2	0	1 2 2-		75	68	7
62	2.15744	4.66E-29	.034	685.624	0	22 22	0	23 22 22+		75	68	7
63	2.16598	3.62E-29	.032	747.867	0	23 23	0	24 23 23+		75	68	7
64	2.17450	2.78E-29	.032	812.798	0	24 24	0	25 24 24+		75	68	7
65	2.18298	2.10E-29	.032	880.413	0	25 25	0	26 25 25+		75	68	7
66	2.19145	1.56E-29	.032	950.711	0	26 26	0	27 26 26+		75	68	7
67	2.19989	1.14E-29	.032	1023.688	0	27 27	0	28 27 27+		75	68	7
68	2.20832	8.28E-30	.032	1099.341	0	28 28	0	29 28 28+		75	68	7
69	2.21674	5.90E-30	.032	1177.668	0	29 29	0	30 29 29+		75	68	7
70	2.22514	4.15E-30	.032	1258.667	0	30 30	0	31 30 30+		75	68	7
71	2.23353	2.87E-30	.032	1342.332	0	31 31	0	32 31 31+		75	68	7
72	2.24192	1.96E-30	.032	1428.663	0	32 32	0	33 32 32+		75	68	7
73	2.25030	1.32E-30	.032	1517.654	0	33 33	0	34 33 33+		75	68	7
74	2.25867	8.79E-31	.032	1609.303	0	34 34	0	35 34 34+		75	68	7
75	2.26704	5.76E-31	.032	1703.607	0	35 35	0	36 35 35+		75	68	7
76	2.27540	3.72E-31	.032	1800.561	0	36 36	0	37 36 36+		75	68	7
77	2.28377	2.38E-31	.032	1900.162	0	37 37	0	38 37 37+		75	68	7
78	2.29213	1.49E-31	.032	2002.406	0	38 38	0	39 38 38+		75	68	7
79	2.30049	9.28E-32	.032	2107.289	0	39 39	0	40 39 39+		75	68	7
80	3.96140	1.94E-28	.050	0.563	0	1 1	0	0 1 1-		75	68	7

RIVERSIDE RESEARCH INSTITUTE

RMI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN (ISOTOPES) (AFCL FORMAT)

AF7K25V0 B0, B1, ETC.: REF. 7, 016-018 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
1	0.00000	0.00E0	.050	0.000	0	1	2	0	0	0	SF	75	68	7
2	7.80360	2.91E-28	.070	0.000	0	1	2	0	1	0	SG	75	68	7
3	9.95599	1.67E-28	.050	0.000	0	2	8	0	1	0	SH	75	68	7
4	11.50856	4.25E-29	.048	4.525	0	2	3	0	1	1	SF	75	68	7
5	13.40060	4.72E-28	.045	2.633	0	2	3	0	2	1	SG	75	68	7
6	15.46998	2.05E-28	.045	2.633	0	3	3	0	2	1	SH	75	68	7
7	16.97828	8.41E-29	.048	9.956	0	3	4	0	2	2	SF	75	68	7
8	18.90961	6.35E-28	.047	8.025	0	3	4	0	3	2	SG	75	68	7
9	20.93973	2.40E-28	.047	8.025	0	4	4	0	3	2	SH	75	68	7
10	22.43321	1.22E-28	.045	18.103	0	4	5	0	3	3	SF	75	68	7
11	24.38978	7.75E-28	.044	16.146	0	4	8	0	4	3	SG	75	68	7
12	26.39469	2.69E-28	.044	16.146	0	5	5	0	4	3	SH	75	68	7
13	27.88690	1.53E-28	.044	28.964	0	5	8	0	4	4	SF	75	68	7
14	29.85639	8.87E-28	.043	26.989	0	5	8	0	5	4	SG	75	68	7
15	31.84241	2.92E-28	.043	26.989	0	6	6	0	5	4	SH	75	68	7
16	33.32407	1.78E-28	.043	42.541	0	6	7	0	5	5	SF	75	68	7
17	35.31509	9.69E-28	.042	40.550	0	6	7	0	6	5	SG	75	68	7
18	37.28562	3.06E-28	.042	40.550	0	7	7	0	6	5	SH	75	68	7
19	38.76386	1.96E-28	.043	58.831	0	7	8	0	6	6	SF	75	68	7
20	40.76842	1.02E-27	.041	56.827	0	7	8	0	7	6	SG	75	68	7
21	42.72546	3.13E-28	.041	56.827	0	8	8	0	7	6	SH	75	68	7
22	44.20080	2.07E-28	.042	77.835	0	8	9	0	7	7	SF	75	68	7
23	46.21758	1.04E-27	.041	75.819	0	8	9	0	8	7	SG	75	68	7
24	48.16245	3.12E-28	.041	73.819	0	9	9	0	8	7	SH	75	68	7
25	49.63509	2.11E-28	.042	99.852	0	9	10	0	8	8	SF	75	68	7
26	51.66320	1.03E-27	.041	97.824	0	9	10	0	9	8	SG	75	68	7
27	53.59681	3.04E-28	.041	97.824	0	10	10	0	9	8	SH	75	68	7
28	55.06678	2.08E-28	.041	123.981	0	10	11	0	9	9	SF	75	68	7
29	57.10558	1.00E-27	.040	121.942	0	10	11	0	10	9	SG	75	68	7
30	59.02856	2.90E-28	.040	121.942	0	11	11	0	10	9	SH	75	68	7
31	60.49582	2.01E-28	.041	151.121	0	11	18	0	10	10	SF	75	68	7
32	62.54486	9.49E-28	.039	149.072	0	11	18	0	11	10	SG	75	68	7
33	64.45768	2.72E-28	.039	149.072	0	12	18	0	11	10	SH	75	68	7
34	65.92213	1.89E-28	.041	180.971	0	12	13	0	11	11	SF	75	68	7
35	67.98106	8.82E-28	.039	178.912	0	12	13	0	12	11	SG	75	68	7
36	69.88407	2.50E-28	.039	178.912	0	13	13	0	12	11	SH	75	68	7
37	71.34558	1.74E-28	.040	213.530	0	13	14	0	12	12	SF	75	68	7
38	73.41411	8.03E-28	.039	211.461	0	13	14	0	13	12	SG	75	68	7
39	75.30761	2.25E-28	.039	211.461	0	14	14	0	13	12	SH	75	68	7
40	76.76602	1.57E-28	.038	248.796	0	14	15	0	13	13	SF	75	68	7
41	78.84394	7.18E-28	.038	246.718	0	14	15	0	14	13	SG	75	68	7
42	80.72815	2.00E-28	.038	246.718	0	15	15	0	14	13	SH	75	68	7
43	82.18328	1.39E-28	.038	286.769	0	15	16	0	14	14	SF	75	68	7
44	84.27043	6.30E-28	.036	284.681	0	15	16	0	15	14	SG	75	68	7
45	86.14551	1.74E-28	.036	284.681	0	16	16	0	15	14	SH	75	68	7
46	87.59720	1.21E-28	.036	327.446	0	16	17	0	15	15	SF	75	68	7
47	89.69343	5.44E-28	.034	325.350	0	16	17	0	16	15	SG	75	68	7

RIVERSIDE RESEARCH INSTITUTE

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFRL FORMAT)
 AF7K25VC BU, B1, ETC.: REF. 7, O16=O18 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V	J' K'	V''	J'' K''	IO	DATE	ISO	MO
48	91.55954	1.49E-28	.034	325.357	0	17 17	0	16 15	SH	75	68	7
49	93.00758	1.03E-28	.037	370.827	0	17 18	0	16 16	GF	75	68	7
50	95.11278	4.61E-28	.035	368.722	0	17 18	0	17 16	SG	75	68	7
51	96.97004	1.26E-28	.035	368.722	0	18 18	0	17 16	SH	75	68	7
52	98.41425	8.67E-29	.037	416.909	0	18 19	0	17 17	GF	75	68	7
53	100.52832	3.85E-28	.036	414.795	0	18 19	0	18 17	SG	75	68	7
54	102.37684	1.05E-28	.036	414.795	0	19 19	0	18 17	SH	75	68	7
55	103.81702	7.16E-29	.037	465.692	0	19 20	0	18 18	GF	75	68	7
56	105.93987	3.17E-28	.036	463.569	0	19 20	0	19 18	SG	75	68	7
57	107.77973	8.56E-29	.036	463.569	0	20 20	0	19 18	SH	75	68	7
58	109.21568	5.82E-29	.036	517.172	0	20 21	0	19 19	GF	75	68	7
59	111.34725	2.56E-28	.035	515.041	0	20 21	0	20 19	SG	75	68	7
60	113.17852	6.90E-29	.035	515.041	0	21 21	0	20 19	SH	75	68	7
61	114.61004	4.65E-29	.036	571.349	0	21 22	0	20 20	GF	75	68	7
62	116.75028	2.04E-28	.035	569.208	0	21 22	0	21 20	SG	75	68	7
63	118.57303	5.47E-29	.035	569.208	0	22 22	0	21 20	SH	75	68	7
64	119.99390	3.66E-29	.035	628.219	0	22 23	0	21 21	GF	75	68	7
65	122.14877	1.60E-28	.035	626.070	0	22 23	0	22 21	SG	75	68	7
66	123.94305	4.28E-29	.035	626.070	0	23 23	0	22 21	SH	75	68	7
67	125.38508	2.84E-29	.036	687.782	0	23 24	0	22 22	GF	75	68	7
68	127.54252	1.24E-28	.034	685.624	0	23 24	0	23 22	SG	75	68	7
69	129.34836	3.30E-29	.034	685.624	0	24 24	0	23 22	SH	75	68	7
70	130.76535	2.17E-29	.035	750.033	0	24 25	0	23 23	GF	75	68	7
71	132.93134	9.41E-29	.032	747.867	0	24 28	0	24 23	SG	75	68	7
72	134.72882	2.50E-29	.032	747.867	0	25 28	0	24 23	SH	75	68	7
73	136.14053	1.63E-29	.034	814.972	0	25 26	0	24 24	GF	75	68	7
74	138.31503	7.06E-29	.032	812.798	0	25 26	0	25 24	SG	75	68	7
75	140.10417	1.87E-29	.032	812.798	0	26 26	0	25 24	SH	75	68	7
76	141.51041	1.21E-29	.032	882.596	0	26 27	0	25 25	GF	75	68	7
77	143.69339	5.22E-29	.032	880.413	0	26 27	0	26 25	SG	75	68	7
78	145.47423	1.38E-29	.032	880.413	0	27 27	0	26 25	SH	75	68	7
79	146.87478	8.45E-30	.032	952.902	0	27 28	0	26 26	GF	75	68	7
80	149.06623	3.81E-29	.032	950.711	0	27 28	0	27 26	SG	75	68	7
81	150.83879	1.01E-29	.032	950.711	0	28 28	0	27 26	SH	75	68	7
82	152.23345	6.37E-30	.032	1025.887	0	28 29	0	27 27	GF	75	68	7
83	154.43335	2.74E-29	.032	1023.688	0	28 29	0	28 27	SG	75	68	7
84	156.19765	7.21E-30	.032	1023.688	0	29 29	0	28 27	SH	75	68	7
85	157.58621	4.52E-30	.032	1101.849	0	29 38	0	28 28	GF	75	68	7
86	159.79453	1.94E-29	.032	1099.341	0	29 30	0	29 28	SG	75	68	7
87	161.55061	5.10E-30	.032	1099.341	0	30 30	0	29 28	SH	75	68	7
88	162.93286	3.17E-30	.032	1179.885	0	30 31	0	29 29	GF	75	68	7
89	165.14960	1.35E-29	.032	1177.668	0	30 31	0	30 29	SG	75	68	7
90	166.89746	3.56E-30	.032	1177.668	0	31 31	0	30 29	SH	75	68	7
91	168.27319	2.19E-30	.032	1260.892	0	31 32	0	30 30	GF	75	68	7
92	170.49833	9.33E-30	.032	1258.667	0	31 32	0	31 30	SG	75	68	7
93	172.23801	2.45E-30	.032	1258.667	0	32 32	0	31 30	SH	75	68	7
94	173.60699	1.49E-30	.032	1344.866	0	32 33	0	31 31	GF	75	68	7

RIVERSIDE RESEARCH INSTITUTE

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF7K25V0 80, B1, ETC.: REF. 7, 016=018 SUBMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	Z''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
95	175.84053	6.34E-30	.032	1342.332	0	32 33	0	32 31	80	75	68	7
96	177.57203	1.66E-30	.032	1342.332	0	33 33	0	32 31	8H	75	68	7
97	178.93407	9.99E-31	.032	1430.905	0	33 34	0	32 32	8F	75	68	7
98	181.17599	4.25E-30	.032	1428.663	0	33 34	0	33 32	80	75	68	7
99	182.89934	1.11E-30	.032	1428.663	0	34 34	0	33 32	8H	75	68	7
100	184.25422	6.61E-31	.032	1519.904	0	34 38	0	33 33	8F	75	68	7
101	186.50451	2.81E-30	.032	1517.654	0	34 38	0	34 33	80	75	68	7
102	188.21971	7.33E-31	.032	1517.654	0	35 38	0	34 33	8H	75	68	7
103	189.56722	4.32E-31	.032	1611.862	0	35 36	0	34 34	8F	75	68	7
104	191.82589	1.83E-30	.032	1609.303	0	35 38	0	35 34	80	75	68	7
105	193.53296	4.77E-31	.032	1609.303	0	36 38	0	35 34	8H	75	68	7
106	194.87289	2.78E-31	.032	1705.874	0	36 37	0	35 35	8F	75	68	7
107	197.13992	1.18E-30	.032	1703.607	0	36 37	0	36 35	80	75	68	7
108	198.83887	3.07E-31	.032	1703.607	0	37 37	0	36 35	8H	75	68	7
109	200.17100	1.77E-31	.032	1802.836	0	37 38	0	36 36	8F	75	68	7
110	202.44640	7.47E-31	.032	1800.861	0	37 38	7	37 36	80	75	68	7
111	204.13724	1.94E-31	.032	1800.861	0	38 38	0	37 36	8H	75	68	7
112	205.46136	1.11E-31	.032	1902.446	0	38 39	0	37 37	8F	75	68	7
113	207.74513	4.68E-31	.032	1900.162	0	38 39	0	38 37	80	75	68	7
114	209.42786	1.21E-31	.032	1900.162	0	39 39	0	38 37	8H	75	68	7
115	210.74376	6.84E-32	.032	2004.698	0	39 40	0	38 38	8F	75	68	7
116	213.03589	2.89E-31	.032	2002.406	0	39 40	0	39 38	80	75	68	7
117	214.71053	7.49E-32	.032	2002.406	0	40 40	0	39 38	8H	75	68	7
118	216.01800	4.17E-32	.032	2109.090	0	40 41	0	39 39	8F	75	68	7
119	218.31849	1.76E-31	.032	2107.289	0	40 41	0	40 39	80	75	68	7
120	219.98504	4.56E-32	.032	2107.289	0	41 41	0	40 39	8H	75	68	7

RIVERSIDE RESEARCH INSTITUTE

RMI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFRL FORMAT)
 AF760K35v0 80, B1, ETC.: REF. 7, 018-018 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
1	1.59501	7.20E-38	.032	3626.050	0	53 53	0	52 53 53-		75	88	7
2	1.60999	2.55E-37	.032	3362.098	0	51 51	0	50 51 51-		75	88	7
3	1.62498	8.58E-37	.032	3107.879	0	49 49	0	48 49 49-		75	88	7
4	1.63999	2.75E-36	.032	2863.432	0	47 47	0	46 47 47-		75	88	7
5	1.65502	8.40E-36	.032	2628.794	0	45 45	0	44 45 45-		75	88	7
6	1.67007	2.44E-35	.032	2403.998	0	43 43	0	42 43 43-		75	88	7
7	1.68514	6.73E-35	.032	2189.078	0	41 41	0	40 41 41-		75	88	7
8	1.70025	1.77E-34	.032	1984.065	0	39 39	0	38 39 39-		75	88	7
9	1.71539	4.41E-34	.032	1788.989	0	37 37	0	36 37 37-		75	88	7
10	1.73056	1.04E-33	.032	1603.877	0	35 35	0	34 35 35-		75	88	7
11	1.74579	2.35E-33	.032	1428.758	0	33 33	0	32 33 33-		75	88	7
12	1.76107	5.01E-33	.032	1263.655	0	31 31	0	30 31 31-		75	88	7
13	1.77642	1.01E-32	.032	1108.594	0	29 29	0	28 29 29-		75	88	7
14	1.79186	1.95E-32	.032	963.597	0	27 27	0	26 27 27-		75	88	7
15	1.80740	3.54E-32	.032	828.684	0	25 25	0	24 25 25-		75	88	7
16	1.82307	6.08E-32	.038	703.875	0	23 23	0	22 23 23-		75	88	7
17	1.83890	9.89E-32	.035	589.188	0	21 21	0	20 21 21-		75	88	7
18	1.85495	1.52E-31	.037	484.641	0	19 19	0	18 19 19-		75	88	7
19	1.87130	2.19E-31	.038	390.246	0	17 17	0	16 17 17-		75	88	7
20	1.88806	2.97E-31	.038	306.019	0	15 15	0	14 15 15-		75	88	7
21	1.90543	3.77E-31	.079	231.971	0	13 13	0	12 13 13-		75	88	7
22	1.90932	1.05E-31	.045	2.052	0	1 1	0	2 1 1+		75	88	7
23	1.92376	4.46E-31	.041	168.112	0	11 11	0	10 11 11-		75	88	7
24	1.94370	4.87E-31	.043	114.452	0	9 9	0	8 9 9-		75	88	7
25	1.96468	2.87E-31	.044	14.777	0	3 3	0	4 3 3+		75	88	7
26	1.96676	4.84E-31	.044	70.995	0	7 7	0	6 7 7-		75	88	7
27	1.99509	4.27E-31	.042	37.747	0	5 5	0	6 5 5+		75	88	7
28	1.99710	4.25E-31	.044	37.745	0	5 5	0	4 5 5-		75	88	7
29	2.01326	5.11E-31	.041	70.944	0	7 7	0	8 7 7+		75	88	7
30	2.01333	5.37E-31	.040	114.257	0	9 9	0	10 9 9+		75	88	7
31	2.01242	3.04E-31	.047	14.689	0	3 3	0	2 3 3-		75	88	7
32	2.03682	5.11E-31	.739	167.979	0	11 11	0	12 11 11+		75	88	7
33	2.07437	4.48E-31	.038	231.802	0	13 13	0	14 13 13+		75	88	7
34	2.09134	3.65E-31	.034	305.816	0	15 15	0	16 15 15+		75	88	7
35	2.10793	2.78E-31	.036	390.010	0	17 17	0	18 17 17+		75	88	7
36	2.12425	1.99E-31	.035	484.371	0	19 19	0	20 19 19+		75	88	7
37	2.14038	1.34E-31	.035	588.887	0	21 21	0	22 21 21+		75	88	7
38	2.15637	8.52E-32	.032	703.842	0	23 23	0	24 23 23+		75	88	7
39	2.17225	5.12E-32	.032	828.319	0	25 25	0	26 25 25+		75	88	7
40	2.18806	2.91E-32	.032	963.201	0	27 27	0	28 27 27+		75	88	7
41	2.20382	1.56E-32	.032	1108.167	0	29 29	0	30 29 29+		75	88	7
42	2.21953	7.97E-33	.032	1263.197	0	31 31	0	32 31 31+		75	88	7
43	2.23522	3.85E-33	.032	1428.268	0	33 33	0	34 33 33+		75	88	7
44	2.25088	1.77E-33	.032	1603.357	0	35 35	0	36 35 35+		75	88	7
45	2.26653	7.70E-34	.032	1788.438	0	37 37	0	38 37 37+		75	88	7
46	2.28217	3.19E-34	.032	1983.483	0	39 39	0	40 39 39+		75	88	7
47	2.29782	1.25E-34	.032	2188.466	0	41 41	0	42 41 41+		75	88	7

RIVERSIDE RESEARCH INSTITUTE

RH: ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF760K35V0 60, 81, ETC.: REF: 7, 018*018 MICROWAVE LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRE	STH	WIDTH	E''	V'	J'	K'	V''	J''	K''	ID	DATE	ISO	MO
48	2.31346	4.69E+35	.032	2403.355	0	43	43	0	44	43	43+		75	88	7
49	2.32911	1.67E+35	.032	2628.120	0	45	45	0	46	45	45+		75	88	7
50	2.34477	5.64E+36	.032	2862.727	0	47	47	0	48	47	47+		75	88	7
51	2.36044	1.81E+36	.032	3107.143	0	49	49	0	50	49	49+		75	88	7
52	2.37612	5.56E+37	.032	3361.332	0	51	51	0	52	51	51+		75	88	7
53	2.39182	1.62E+37	.032	3625.267	0	53	53	0	54	53	53+		75	88	7
54	3.96171	3.73E+31	.050	0.000	0	1	1	0	0	1	1+		75	88	7

RIVERSIDE RESEARCH INSTITUTE

NRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFRL FORMAT)

AF7K35V0 B0, B1, ETC.: REF. 7, O18-O18 SUBMM LINES, KNOBENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
1	10.72714	8.00E-32	.048	3.962	0	2 3	0	1 1	SF	75	88	7
2	12.63646	9.07E-31	.045	2.052	0	2 3	0	2 1	SG	75	88	7
3	14.68188	4.00E-31	.045	2.052	0	3 3	0	2 1	SH	75	88	7
4	21.00418	2.32E-31	.045	16.741	0	4 5	0	3 3	SF	75	88	7
5	22.96886	1.50E-30	.044	14.777	0	4 5	0	4 3	SG	75	88	7
6	24.96596	5.26E-31	.044	14.777	0	5 5	0	4 3	SH	75	88	7
7	31.25291	3.45E-31	.043	39.743	0	6 7	0	5 5	SF	75	88	7
8	33.24801	1.89E-30	.042	37.747	0	6 7	0	6 5	SG	75	88	7
9	35.21477	6.01E-31	.042	37.747	0	7 7	0	6 5	SH	75	88	7
10	41.43958	4.05E-31	.042	72.962	0	8 9	0	7 7	SF	75	88	7
11	43.50784	2.05E-30	.041	70.944	0	8 9	0	8 7	SG	75	88	7
12	45.45154	6.18E-31	.041	70.944	0	9 9	0	8 7	SH	75	88	7
13	51.71688	4.15E-31	.041	116.396	0	10 11	0	9 9	SF	75	88	7
14	53.75522	2.00E-30	.040	114.357	0	10 11	0	10 9	SG	75	88	7
15	55.67897	5.83E-31	.040	114.357	0	11 11	0	10 9	SH	75	88	7
16	61.92483	3.83E-31	.041	170.036	0	12 13	0	11 11	SF	75	88	7
17	63.99164	1.79E-30	.039	167.979	0	12 13	0	12 11	SG	75	88	7
18	65.89707	5.10E-31	.039	167.979	0	13 13	0	12 11	SH	75	88	7
19	72.14261	3.25E-31	.038	233.876	0	14 15	0	13 13	SF	75	88	7
20	74.21698	1.49E-30	.038	231.802	0	14 15	0	14 13	SG	75	88	7
21	76.10504	4.16E-31	.038	231.802	0	15 15	0	14 13	SH	75	88	7
22	82.33910	2.56E-31	.036	307.907	0	16 17	0	15 15	SF	75	88	7
23	84.43045	1.16E-30	.034	305.816	0	16 17	0	16 15	SG	75	88	7
24	86.30175	3.19E-31	.034	305.816	0	17 17	0	16 15	SH	75	88	7
25	92.52303	1.89E-31	.037	392.117	0	18 19	0	17 17	SF	75	88	7
26	94.63096	8.42E-31	.036	390.010	0	18 19	0	18 17	SG	75	88	7
27	96.48591	2.29E-31	.036	390.010	0	19 19	0	18 17	SH	75	88	7
28	102.69304	1.31E-31	.036	486.495	0	20 21	0	19 19	SF	75	88	7
29	104.81729	5.77E-31	.035	484.371	0	20 21	0	20 19	SG	75	88	7
30	106.65619	1.56E-31	.035	484.371	0	21 21	0	20 19	SH	75	88	7
31	112.84773	8.51E-32	.035	591.027	0	22 23	0	21 21	SF	75	88	7
32	114.98811	3.72E-31	.035	588.887	0	22 23	0	22 21	SG	75	88	7
33	116.81117	9.98E-32	.035	588.887	0	23 23	0	22 21	SH	75	88	7
34	122.98568	5.23E-32	.035	705.698	0	24 25	0	23 23	SF	75	88	7
35	125.14205	2.27E-31	.032	703.542	0	24 25	0	24 23	SG	75	88	7
36	126.94945	6.05E-32	.032	703.542	0	25 25	0	24 23	SH	75	88	7
37	133.10546	3.03E-32	.032	830.491	0	26 27	0	25 25	SF	75	88	7
38	135.27771	1.31E-31	.032	828.319	0	26 27	0	26 25	SG	75	88	7
39	137.06957	3.47E-32	.032	828.319	0	27 27	0	26 25	SH	75	88	7
40	143.20562	1.66E-32	.032	965.389	0	28 29	0	27 27	SF	75	88	7
41	145.39368	7.16E-32	.032	963.201	0	28 29	0	28 27	SG	75	88	7
42	147.17011	1.89E-32	.032	963.201	0	29 29	0	28 27	SH	75	88	7
43	153.28470	8.56E-33	.032	1110.371	0	30 31	0	29 29	SF	75	88	7
44	155.48852	3.71E-32	.032	1108.167	0	30 31	0	30 29	SG	75	88	7
45	157.24960	9.75E-33	.032	1108.167	0	31 31	0	30 29	SH	75	88	7
46	163.34126	4.27E-33	.032	1265.416	0	32 33	0	31 31	SF	75	88	7
47	165.56079	1.82E-32	.032	1263.197	0	32 33	0	32 31	SG	75	88	7

RIVERSIDE RESEARCH INSTITUTE

IRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF7K35VC B0, B1, ETC.: REF. 7, 018-018 SUMM LINES, KRUPENIE WIDTHS, V = 0

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
48	167.30658	4.77E-33	.032	1263.197	0	33 33	0	32 31	SM	75	88	7
49	173.37582	1.99E-33	.032	1430.503	0	34 35	0	33 33	SF	75	88	7
50	175.60903	8.49E-33	.032	1428.268	0	34 35	0	34 33	SO	75	88	7
51	177.33960	2.22E-33	.032	1428.268	0	35 35	0	34 33	SM	75	88	7
52	183.58092	8.85E-34	.032	1605.608	0	36 37	0	35 35	SF	75	88	7
53	185.63180	3.76E-33	.032	1603.357	0	36 37	0	36 35	SO	75	88	7
54	187.34718	9.79E-34	.032	1603.357	0	37 37	0	36 35	SM	75	88	7
55	193.36110	3.73E-34	.032	1790.704	0	38 39	0	37 37	SF	75	88	7
56	195.62763	1.58E-33	.032	1788.438	0	39 39	0	38 37	SO	75	88	7
57	197.32787	4.10E-34	.032	1788.438	0	39 39	0	38 37	SM	75	88	7
58	203.31288	1.49E-34	.032	1985.765	0	40 41	0	39 39	SF	75	88	7
59	205.59506	6.31E-34	.032	1983.483	0	40 41	0	40 39	SO	75	88	7
60	207.28020	1.64E-34	.032	1983.483	0	41 41	0	40 39	SM	75	88	7
61	213.23481	5.68E-35	.032	2190.764	0	42 43	0	41 41	SF	75	88	7
62	215.53263	2.40E-34	.032	2188.466	0	42 43	0	42 41	SO	75	88	7
63	217.20270	6.20E-35	.032	2188.466	0	43 43	0	42 41	SM	75	88	7
64	223.12542	2.06E-35	.032	2405.668	0	44 45	0	43 43	SF	75	88	7
65	225.43888	8.65E-35	.032	2403.355	0	44 45	0	44 43	SO	75	88	7
66	227.09390	2.24E-35	.032	2403.355	0	45 45	0	44 43	SM	75	88	7
67	232.98323	7.08E-36	.032	2630.449	0	46 47	0	45 45	SF	75	88	7
68	235.31234	2.98E-35	.032	2628.120	0	46 47	0	46 45	SO	75	88	7
69	236.95233	7.68E-36	.032	2628.120	0	47 47	0	46 45	SM	75	88	7
70	242.80677	2.32E-36	.032	2865.072	0	48 49	0	47 47	SF	75	88	7
71	245.15154	9.73E-36	.032	2862.727	0	48 49	0	48 47	SO	75	88	7
72	246.77652	2.51E-36	.032	2862.727	0	49 49	0	48 47	SM	75	88	7
73	252.59457	7.24E-37	.032	3109.504	0	50 51	0	49 49	SF	75	88	7
74	254.95501	3.03E-36	.032	3107.143	0	50 51	0	50 49	SO	75	88	7
75	256.56500	7.80E-37	.032	3107.143	0	51 51	0	50 49	SM	75	88	7
76	262.34517	2.15E-37	.032	3363.708	0	52 53	0	51 51	SF	75	88	7
77	264.72129	8.99E-37	.032	3361.332	0	52 53	0	52 51	SO	75	88	7
78	266.31630	2.31E-37	.032	3361.332	0	53 53	0	52 51	SM	75	88	7
79	272.05709	6.08E-38	.032	3627.649	0	54 55	0	53 53	SF	75	88	7
80	274.44891	2.54E-37	.032	3625.257	0	54 55	0	54 53	SO	75	88	7
81	276.02896	6.52E-38	.032	3625.257	0	55 55	0	54 53	SM	75	88	7

RIVERSIDE RESEARCH INSTITUTE

RRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AF560K15v1 80, 81, ETC.: REF. 5, 016=016 MICROWAVE LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V	J' K'	V''	J'' K''	ID	DATE	ISO	MO
1	1.52311	1.27E-36	.032	5585.860	1	53 53	1	52 53 53-		75	66	7
2	1.54128	5.21E-36	.032	5292.844	1	51 51	1	50 51 51-		75	66	7
3	1.55948	2.02E-35	.032	5010.588	1	49 49	1	48 49 49-		75	66	7
4	1.57776	7.43E-35	.032	4739.137	1	47 47	1	46 47 47-		75	66	7
5	1.59594	2.58E-34	.032	4478.538	1	45 45	1	44 45 45-		75	66	7
6	1.61420	8.40E-34	.032	4228.832	1	43 43	1	42 43 43-		75	66	7
7	1.63250	2.65E-33	.032	3990.062	1	41 41	1	40 41 41-		75	66	7
8	1.65084	7.80E-33	.032	3762.267	1	39 39	1	38 39 39-		75	66	7
9	1.66921	2.17E-32	.032	3545.485	1	37 37	1	36 37 37-		75	66	7
10	1.68764	5.71E-32	.032	3339.751	1	35 35	1	34 35 35-		75	66	7
11	1.70613	1.42E-31	.032	3145.099	1	33 33	1	32 33 33-		75	66	7
12	1.72468	3.33E-31	.032	2961.562	1	31 31	1	30 31 31-		75	66	7
13	1.74332	7.36E-31	.032	2789.170	1	29 29	1	28 29 29-		75	66	7
14	1.76207	1.53E-30	.032	2627.950	1	27 27	1	26 27 27-		75	66	7
15	1.78094	3.01E-30	.032	2477.929	1	25 25	1	24 25 25-		75	66	7
16	1.79998	5.57E-30	.038	2339.133	1	23 23	1	22 23 23-		75	66	7
17	1.81923	9.67E-30	.035	2211.583	1	21 21	1	20 21 21-		75	66	7
18	1.83877	1.58E-29	.037	2095.301	1	19 19	1	18 19 19-		75	66	7
19	1.85869	2.41E-29	.038	1990.305	1	17 17	1	16 17 17-		75	66	7
20	1.87915	3.43E-29	.038	1896.613	1	15 15	1	14 15 15-		75	66	7
21	1.88985	1.42E-29	.045	1858.465	1	1 1	1	2 1 1-		75	66	7
22	1.90041	4.56E-29	.039	1814.239	1	13 13	1	12 13 13-		75	66	7
23	1.92295	5.61E-29	.041	1743.197	1	11 11	1	10 11 11-		75	66	7
24	1.94764	6.33E-29	.043	1683.497	1	9 9	1	8 9 9-		75	66	7
25	1.96204	3.92E-29	.044	1672.612	1	3 3	1	4 3 3-		75	66	7
26	1.97649	6.48E-29	.044	1635.147	1	7 7	1	6 7 7-		75	66	7
27	2.00064	5.80E-29	.042	1598.164	1	5 5	1	6 5 5-		75	66	7
28	2.01509	5.84E-29	.044	1598.149	1	5 5	1	4 5 5-		75	66	7
29	2.02949	6.85E-29	.041	1635.094	1	7 7	1	6 7 7-		75	66	7
30	2.05418	7.06E-29	.040	1683.390	1	4 9	1	10 9 9-		75	66	7
31	2.07672	6.55E-29	.039	1743.043	1	11 11	1	12 11 11-		75	66	7
32	2.08728	4.32E-29	.047	1572.486	1	3 3	1	2 3 3-		75	66	7
33	2.09798	5.56E-29	.038	1814.041	1	13 13	1	14 13 13-		75	66	7
34	2.11844	4.37E-29	.034	1896.373	1	15 15	1	16 15 15-		75	66	7
35	2.13836	3.19E-29	.036	1990.025	1	17 17	1	18 17 17-		75	66	7
36	2.15790	2.17E-29	.035	2094.982	1	19 19	1	20 19 19-		75	66	7
37	2.17715	1.39E-29	.035	2211.225	1	21 21	1	22 21 21-		75	66	7
38	2.19619	8.29E-30	.032	2338.737	1	23 23	1	24 23 23-		75	66	7
39	2.21506	4.66E-30	.032	2477.495	1	25 25	1	26 25 25-		75	66	7
40	2.23381	2.47E-30	.032	2627.478	1	27 27	1	28 27 27-		75	66	7
41	2.25245	1.23E-30	.032	2788.661	1	29 29	1	30 29 29-		75	66	7
42	2.27100	5.78E-31	.032	2961.016	1	31 31	1	32 31 31-		75	66	7
43	2.28949	2.56E-31	.032	3144.516	1	33 33	1	34 33 33-		75	66	7
44	2.30792	1.07E-31	.032	3339.131	1	35 35	1	36 35 35-		75	66	7
45	2.32629	4.22E-32	.032	3544.828	1	37 37	1	38 37 37-		75	66	7
46	2.34463	1.58E-32	.032	3761.573	1	39 39	1	40 39 39-		75	66	7
47	2.36293	5.56E-33	.032	3989.332	1	41 41	1	42 41 41-		75	66	7

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NRI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPIES (AFCL FORMAT)
 AFS60K15v1 80, 81, ETC.: REF. 5, O16=O16 MICROWAVE LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
48	2.38119	1.85E-33	.032	4228.065	1	43 43	1	44 43 43+		75	66	7
49	2.39943	5.85E-34	.032	4477.734	1	45 45	1	46 45 45+		75	66	7
50	2.41765	1.75E-34	.032	4738.297	1	47 47	1	48 47 47+		75	66	7
51	2.43585	4.94E-35	.032	5009.711	1	49 49	1	50 49 49+		75	66	7
52	2.45402	1.32E-35	.032	5291.932	1	51 51	1	52 51 51+		75	66	7
53	2.47218	3.36E-36	.032	5584.911	1	53 53	1	54 53 53+		75	66	7
54	3.97713	5.17E-29	.050	1596.378	1	1 1	1	0 1 1-		75	66	7

RIVERSIDE RESEARCH INSTITUTE

RMI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFRL FORMAT)

AF5K10V1 BO, B1, ETC.: REF. 5, 016-016 SUBMM LINES, KRUPENIE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
1	12.13118	1.14E-29	.048	1560.355	1	2 3	1	1 1	SF	75	66	7
2	14.02102	1.25E-28	.045	1558.465	1	2 3	1	2 1	SG	75	66	7
3	16.10831	5.38E-29	.045	1558.465	1	3 2	1	2 1	SH	75	66	7
4	23.57570	3.24E-29	.045	1574.874	1	4 0	1	3 3	SF	75	66	7
5	25.53774	2.05E-28	.044	1572.612	1	4 5	1	4 3	SG	75	66	7
6	27.55283	7.08E-29	.044	1572.612	1	5 5	1	4 3	SH	75	66	7
7	30.98245	4.71E-29	.043	1600.164	1	6 7	1	5 5	SF	75	66	7
8	36.98309	2.55E-28	.042	1598.164	1	6 7	1	6 5	SG	75	66	7
9	38.95958	8.01E-29	.042	1598.164	1	7 7	1	6 5	SH	75	66	7
10	46.37341	5.40E-29	.042	1637.123	1	8 9	1	7 7	SF	75	66	7
11	48.40290	2.71E-28	.041	1635.094	1	8 9	1	8 7	SG	75	66	7
12	50.35054	8.09E-29	.041	1635.094	1	9 9	1	8 7	SH	75	66	7
13	57.75231	5.37E-29	.041	1685.444	1	10 11	1	9 9	SF	75	66	7
14	59.80650	2.58E-28	.040	1683.390	1	10 11	1	10 9	SG	75	66	7
15	61.72944	7.45E-29	.040	1683.390	1	11 11	1	10 9	SH	75	66	7
16	69.11929	4.80E-29	.041	1745.120	1	12 13	1	11 11	SF	75	66	7
17	71.19601	2.24E-28	.039	1743.043	1	12 13	1	12 11	SG	75	66	7
18	73.09642	6.32E-29	.039	1743.043	1	13 13	1	12 11	SH	75	66	7
19	80.47340	3.92E-29	.038	1816.139	1	14 15	1	13 13	SF	75	66	7
20	82.57138	1.79E-28	.038	1814.041	1	14 15	1	14 13	SG	75	66	7
21	84.45053	4.97E-29	.038	1814.041	1	15 15	1	14 13	SH	75	66	7
22	91.81322	2.96E-29	.036	1898.492	1	16 17	1	15 15	SF	75	66	7
23	93.93166	1.33E-28	.034	1896.373	1	16 17	1	16 15	SG	75	66	7
24	95.79035	3.65E-29	.034	1896.373	1	17 17	1	16 15	SH	75	66	7
25	103.13716	2.08E-29	.037	1992.164	1	18 19	1	17 17	SF	75	66	7
26	105.27552	9.23E-29	.036	1990.025	1	18 19	1	18 17	SG	75	66	7
27	107.11429	2.50E-29	.036	1990.025	1	19 19	1	18 17	SH	75	66	7
28	114.44353	1.36E-29	.036	2097.140	1	20 21	1	19 19	SF	75	66	7
29	116.60142	5.99E-29	.035	2094.982	1	20 21	1	20 19	SG	75	66	7
30	118.42066	1.61E-29	.035	2094.982	1	21 21	1	20 19	SH	75	66	7
31	125.73056	8.35E-30	.035	2213.402	1	22 23	1	21 21	SF	75	66	7
32	127.90771	3.64E-29	.035	2211.225	1	22 23	1	22 21	SG	75	66	7
33	129.70769	9.73E-30	.035	2211.225	1	23 23	1	22 21	SH	75	66	7
34	136.99447	4.80E-30	.035	2340.933	1	24 24	1	23 23	SF	75	66	7
35	139.19266	2.08E-29	.032	2338.737	1	24 24	1	24 23	SG	75	66	7
36	140.97360	5.53E-30	.032	2338.737	1	25 25	1	24 23	SH	75	66	7
37	148.23945	2.60E-30	.032	2479.710	1	26 27	1	25 25	SF	75	66	7
38	150.45451	1.12E-29	.032	2477.495	1	26 27	1	26 25	SG	75	66	7
39	152.21658	2.96E-30	.032	2477.495	1	27 27	1	26 25	SH	75	66	7
40	159.45767	1.32E-30	.032	2629.712	1	28 29	1	27 27	SF	75	66	7
41	161.69148	5.68E-30	.032	2627.478	1	28 29	1	28 27	SG	75	66	7
42	163.43480	1.49E-30	.032	2627.478	1	29 29	1	28 27	SH	75	66	7
43	170.64931	6.34E-31	.032	2790.913	1	30 31	1	29 29	SF	75	66	7
44	172.90175	2.71E-30	.032	2788.661	1	30 31	1	30 29	SG	75	66	7
45	174.62644	7.11E-31	.032	2788.661	1	31 31	1	30 29	SH	75	66	7
46	181.81251	2.86E-31	.032	2963.287	1	32 33	1	31 31	SF	75	66	7
47	184.08351	1.22E-30	.032	2961.016	1	32 33	1	32 31	SG	75	66	7

RIVERSIDE RESEARCH INSTITUTE

NMI ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

AFSK15V1 B0, B1, ETC.: REF. 5, 016-016 SUBMM LINES, KRUPPENLE WIDTHS, V = 1

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	MO
48	165.78964	3.19E-31	.032	2961.016	1	33 33	1	32 31	SH	75	66	7
49	192.94544	1.22E-31	.032	3146.806	1	34 35	1	33 33	SF	75	66	7
50	195.23493	5.19E-31	.032	3144.516	1	34 35	1	34 33	SG	75	66	7
51	196.92257	1.35E-31	.032	3144.516	1	35 35	1	34 33	SH	75	66	7
52	204.04625	4.92E-32	.032	3341.439	1	36 37	1	35 35	SF	75	66	7
53	206.35417	2.08E-31	.032	3339.131	1	36 37	1	36 35	SG	75	66	7
54	208.02338	5.42E-32	.032	3339.131	1	37 37	1	36 35	SH	75	66	7
55	215.11309	1.87E-32	.032	3547.154	1	38 39	1	37 37	SF	75	66	7
56	217.43938	7.91E-32	.032	3544.828	1	38 39	1	38 37	SG	75	66	7
57	219.09022	2.05E-32	.032	3544.828	1	39 39	1	38 37	SH	75	66	7
58	226.14411	6.73E-33	.032	3763.918	1	40 41	1	39 39	SF	75	66	7
59	228.44874	2.84E-32	.032	3761.573	1	40 41	1	40 39	SG	75	66	7
60	230.12124	7.35E-33	.032	3761.573	1	41 41	1	40 39	SH	75	66	7
61	237.13745	2.29E-33	.032	3991.695	1	42 43	1	41 41	SF	75	66	7
62	239.50038	9.63E-33	.032	3989.332	1	42 43	1	42 41	SG	75	66	7
63	241.11458	2.49E-33	.032	3989.332	1	43 43	1	42 41	SH	75	66	7
64	248.09127	7.36E-34	.032	4230.446	1	44 45	1	43 43	SF	75	66	7
65	250.47247	3.09E-33	.032	4228.065	1	44 45	1	44 43	SG	75	66	7
66	252.06840	7.98E-34	.032	4228.065	1	45 45	1	44 43	SH	75	66	7
67	259.00371	2.24E-34	.032	4480.134	1	46 47	1	45 45	SF	75	66	7
68	261.40314	9.40E-34	.032	4477.734	1	46 47	1	46 45	SG	75	66	7
69	262.98084	2.42E-34	.032	4477.734	1	47 47	1	46 45	SH	75	66	7
70	269.87291	6.46E-35	.032	4740.715	1	48 49	1	47 47	SF	75	66	7
71	272.29056	2.71E-34	.032	4738.297	1	48 49	1	48 47	SG	75	66	7
72	273.85004	6.96E-35	.032	4738.297	1	49 49	1	48 47	SH	75	66	7
73	280.69701	1.76E-35	.032	5012.147	1	50 51	1	49 49	IF	75	66	7
74	283.13286	7.38E-35	.032	5009.711	1	50 51	1	50 49	SG	75	66	7
75	284.67414	1.90E-35	.032	5009.711	1	51 51	1	50 49	SH	75	66	7
76	291.47417	4.56E-36	.032	5294.386	1	52 53	1	51 51	SF	75	66	7
77	293.92619	1.91E-35	.032	5291.932	1	52 53	1	52 51	SG	75	66	7
78	295.45130	4.89E-36	.032	5291.932	1	53 53	1	52 51	SH	75	66	7
79	302.20252	1.12E-36	.032	5587.911	1	54 55	1	53 53	SF	75	66	7
80	304.67470	4.67E-36	.032	5584.911	1	54 55	1	54 53	SG	75	66	7
81	306.17965	1.20E-36	.032	5584.911	1	55 55	1	54 53	SH	75	66	7

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APPENDIX G

RRI Absorption Line Parameters
for Molecular Oxygen Isotopes
 $^{16}\text{O}^{16}\text{O}$, $^{16}\text{O}^{18}\text{O}$, and $^{18}\text{O}^{18}\text{O}$ Whose
Line Strengths Exceed 3.7 E-30

See text, page 33 for discussion of the relationship of the file OXYGENEXIST to the eight files listed in Appendix F. The units are the same as in Appendix F.

RIVERSIDE RESEARCH INSTITUTE

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

ALL LINES OF 016-016, 016-018, AND 018-018 WITH V = 0 OR 1
AND WHOSE STRENGTHS EXCEED 3.7E-30 INV CM PER MOLECULE PER CM SQ
AT 296K. LINEWIDTHS INTERPOLATED FROM KRUPENIE'S COMPILATION
B0, B1, B2, ETC., FROM REF. 7 FOR V = 0, FROM REF. 5 FOR V = 1.

	FREQ	STRENGTH	WIDTH	E	V	J	K	V'	J'	K'	IO	DATE	ISO	MO
1	1.64953	4.62E-30	.032	2460.774	0	41	41	0	40	41	41	75	66	7
2	1.66655	1.38E-29	.032	2230.425	0	39	39	0	38	39	39	75	66	7
3	1.68362	3.87E-29	.032	2011.215	0	37	37	0	36	37	37	75	66	7
4	1.70076	1.03E-28	.032	1803.180	0	35	35	0	34	35	35	75	66	7
5	1.71796	2.58E-28	.032	1606.353	0	33	33	0	32	33	33	75	66	7
6	1.73524	6.09E-28	.032	1420.767	0	31	31	0	30	31	31	75	66	7
7	1.75262	1.36E-27	.032	1246.452	0	29	29	0	28	29	29	75	66	7
8	1.76431	3.73E-30	.032	1178.121	0	29	29	0	28	29	29	75	66	7
9	1.77012	2.85E-27	.032	1083.436	0	27	27	0	26	27	27	75	66	7
10	1.77256	5.33E-30	.032	1099.777	0	28	28	0	27	28	28	75	66	7
11	1.78084	7.49E-30	.032	1024.107	0	27	27	0	26	27	27	75	66	7
12	1.78776	5.63E-27	.032	931.745	0	25	25	0	24	25	25	75	66	7
13	1.78914	1.04E-29	.032	951.113	0	26	26	0	25	26	26	75	66	7
14	1.79748	1.42E-29	.032	880.799	0	25	25	0	24	25	25	75	66	7
15	1.79998	5.57E-30	.038	2339.133	1	23	23	1	22	23	23	75	66	7
16	1.80558	1.05E-26	.038	791.405	0	23	23	0	22	23	23	75	66	7
17	1.80586	1.91E-29	.035	813.167	0	24	24	0	23	24	24	75	66	7
18	1.81428	2.54E-29	.038	748.219	0	23	23	0	22	23	23	75	66	7
19	1.81923	9.47E-30	.035	2211.583	1	21	21	1	20	21	21	75	66	7
20	1.82275	3.32E-29	.037	685.959	0	22	22	0	21	22	22	75	66	7
21	1.82363	1.83E-26	.035	662.437	0	21	21	0	20	21	21	75	66	7
22	1.83127	4.28E-29	.035	626.388	0	21	21	0	20	21	21	75	66	7
23	1.83877	1.58E-29	.037	2095.301	1	19	19	1	18	19	19	75	66	7
24	1.83986	5.43E-29	.036	569.509	0	20	20	0	19	20	20	75	66	7
25	1.84199	3.00E-26	.037	544.863	0	19	19	0	18	19	19	75	66	7
26	1.84852	6.78E-29	.037	515.324	0	19	19	0	18	19	19	75	66	7
27	1.85727	8.34E-29	.038	463.835	0	18	18	0	17	18	18	75	66	7
28	1.85869	2.41E-29	.038	1990.305	1	17	17	1	16	17	17	75	66	7
29	1.86075	4.60E-26	.038	438.702	0	17	17	0	16	17	17	75	66	7
30	1.86611	1.01E-28	.038	415.043	0	17	17	0	16	17	17	75	66	7
31	1.87509	1.20E-28	.038	368.952	0	16	16	0	15	16	16	75	66	7
32	1.87679	2.74E-26	.045	2.084	0	1	1	0	2	1	1	75	66	7
33	1.87915	3.43E-29	.038	1896.813	1	15	15	1	14	15	15	75	66	7
34	1.88008	6.58E-26	.038	343.970	0	15	15	0	14	15	15	75	66	7
35	1.88420	1.41E-28	.038	325.562	0	15	15	0	14	15	15	75	66	7
36	1.88985	1.42E-29	.045	1558.465	1	1	1	1	2	1	1	75	66	7
37	1.89204	5.40E-29	.045	2.633	0	1	1	0	2	1	1	75	66	7
38	1.89350	1.62E-28	.039	284.875	0	14	14	0	13	14	14	75	66	7
39	1.90026	8.77E-26	.039	260.683	0	13	13	0	12	13	13	75	66	7
40	1.90041	4.56E-29	.039	1814.239	1	13	13	1	12	13	13	75	66	7
41	1.90302	1.83E-28	.039	246.893	0	13	13	0	12	13	13	75	66	7
42	1.91282	2.03E-28	.040	211.617	0	12	12	0	11	12	12	75	66	7
43	1.92175	1.08E-29	.041	188.853	0	11	11	0	10	11	11	75	66	7
44	1.92295	5.61E-29	.041	1743.197	1	11	11	1	10	11	11	75	66	7

RIVERSIDE RESEARCH INSTITUTE

OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (TABLE FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	ID	DATE	ISO	NO
45	1.92298	2.21E+28	.041	179.048	0	11 11	0	10 11 11+		75	68	7
46	1.93133	1.03E+28	.047	8.025	0	2 2	0	3 2 2+		75	68	7
47	1.93361	2.36E+28	.042	149.187	0	10 10	0	9 10 10+		75	68	7
48	1.94488	2.46E+28	.043	122.036	0	9 9	0	8 9 9+		75	68	7
49	1.94548	1.22E+25	.043	128.492	0	9 9	0	8 9 9+		75	68	7
50	1.94764	6.33E+29	.043	1683.497	1	9 9	1	8 9 9+		75	68	7
51	1.94957	7.55E+26	.044	16.388	0	3 3	0	4 3 3+		75	68	7
52	1.95657	1.48E+28	.044	16.146	0	3 3	0	4 3 3+		75	68	7
53	1.95705	2.50E+28	.044	97.595	0	8 8	0	7 8 8+		75	68	7
54	1.96204	3.92E+29	.044	1572.612	1	3 3	1	4 3 3+		75	68	7
55	1.97052	2.48E+28	.044	75.865	0	7 7	0	6 7 7+		75	68	7
56	1.97351	1.26E+25	.044	79.607	0	7 7	0	6 7 7+		75	68	7
57	1.97549	1.87E+28	.043	26.989	0	4 4	0	5 4 4+		75	68	7
58	1.97649	6.48E+29	.044	1635.147	1	7 7	1	6 7 7+		75	68	7
59	1.98602	2.39E+28	.044	56.845	0	6 6	0	5 6 6+		75	68	7
60	1.98774	1.11E+25	.042	42.224	0	5 5	0	6 5 5+		75	68	7
61	1.99103	2.19E+28	.042	40.550	0	5 5	0	6 5 5+		75	68	7
62	2.00064	5.80E+29	.042	1598.164	1	5 5	1	6 5 5+		75	68	7
63	2.00455	2.44E+28	.041	56.827	0	6 6	0	7 6 6+		75	68	7
64	2.00491	2.21E+28	.044	40.536	0	5 5	0	4 5 5+		75	68	7
65	2.01159	1.13E+25	.044	42.200	0	5 5	0	4 5 5+		75	68	7
66	2.01509	5.84E+29	.044	1598.149	1	5 5	1	4 5 5+		75	68	7
67	2.01589	1.31E+25	.041	79.565	0	7 7	0	8 7 7+		75	68	7
68	2.01677	2.61E+28	.041	75.819	0	7 7	0	8 7 7+		75	68	7
69	2.02811	2.69E+28	.041	97.524	0	8 8	0	9 8 8+		75	68	7
70	2.02949	6.85E+29	.041	1635.094	1	7 7	1	8 7 7+		75	68	7
71	2.03011	1.95E+28	.045	26.934	0	4 4	0	3 4 4+		75	68	7
72	2.03821	2.71E+28	.040	121.942	0	9 9	0	10 9 9+		75	68	7
73	2.03976	1.35E+25	.040	128.398	0	9 9	0	10 9 9+		75	68	7
74	2.04904	2.65E+28	.039	149.072	0	10 10	0	11 10 10+		75	68	7
75	2.05418	7.06E+29	.040	1683.390	1	9 9	1	10 9 9+		75	68	7
76	2.05892	2.54E+28	.039	178.912	0	11 11	0	12 11 11+		75	68	7
77	2.06143	1.25E+25	.039	188.714	0	11 11	0	12 11 11+		75	68	7
78	2.06453	2.38E+28	.039	211.461	0	12 12	0	13 12 12+		75	68	7
79	2.06938	1.61E+28	.047	16.033	0	3 3	0	2 3 3+		75	68	7
80	2.07672	6.55E+29	.039	1743.043	1	11 11	1	12 11 11+		75	68	7
81	2.07792	2.18E+28	.038	246.718	0	13 13	0	14 13 13+		75	68	7
82	2.08181	1.05E+25	.038	260.501	0	13 13	0	14 13 13+		75	68	7
83	2.08432	8.41E+26	.047	16.253	0	3 3	0	2 3 3+		75	68	7
84	2.08715	1.97E+28	.036	284.681	0	14 14	0	15 14 14+		75	68	7
85	2.08728	4.32E+29	.047	1572.486	1	3 3	1	2 3 3+		75	68	7
86	2.09623	1.74E+28	.034	325.350	0	15 15	0	16 15 15+		75	68	7
87	2.09798	5.56E+29	.038	1814.041	1	13 13	1	14 13 13+		75	68	7
88	2.10139	8.23E+26	.034	343.748	0	15 15	0	16 15 15+		75	68	7
89	2.10519	1.52E+28	.035	368.722	0	16 16	0	17 16 16+		75	68	7
90	2.11406	1.30E+28	.036	414.795	0	17 17	0	18 17 17+		75	68	7
91	2.11644	4.37E+29	.034	1896.373	1	15 15	1	16 15 15+		75	68	7
92	2.12042	5.97E+26	.036	438.442	0	17 17	0	18 17 17+		75	68	7
93	2.12285	1.09E+28	.036	463.569	0	18 18	0	19 18 18+		75	68	7
94	2.13158	9.03E+29	.035	515.041	0	19 19	0	20 19 19+		75	68	7

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OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	IC	DATE	ISO	MO
95	2.13836	3.19E-29	.036	1990.025	1	17 17	1	18 17 17+		75	66	7
96	2.13907	4.04E-26	.035	544.566	0	19 19	0	20 19 19+		75	66	7
97	2.14024	7.35E-29	.035	569.208	0	20 20	0	21 20 20+		75	64	7
98	2.14886	5.90E-29	.035	626.070	0	21 21	0	22 21 21+		75	64	7
99	2.15239	1.18E-28	.048	7.804	0	2 2	0	1 2 2+		75	64	7
100	2.15744	4.66E-29	.034	685.624	0	22 22	0	23 22 22+		75	64	7
101	2.15746	2.56E-26	.035	662.103	0	21 21	0	22 21 21+		75	64	7
102	2.15790	2.17E-29	.035	2094.982	1	19 19	1	20 19 19+		75	66	7
103	2.16598	3.62E-29	.032	747.867	0	23 23	0	24 23 23+		75	64	7
104	2.17450	2.78E-29	.032	812.798	0	24 24	0	25 24 24+		75	64	7
105	2.17564	1.52E-26	.032	791.034	0	23 23	0	24 23 23+		75	66	7
106	2.17715	1.39E-29	.035	2211.225	1	21 21	1	22 21 21+		75	66	7
107	2.18298	2.10E-29	.032	880.413	0	25 25	0	26 25 25+		75	68	7
108	2.19145	1.56E-29	.032	950.711	0	26 26	0	27 26 26+		75	68	7
109	2.19368	8.49E-27	.032	931.339	0	25 25	0	26 25 25+		75	66	7
110	2.19619	8.29E-30	.032	2338.737	1	23 23	1	24 23 23+		75	66	7
111	2.19989	1.14E-29	.032	1023.688	0	27 27	0	28 27 27+		75	68	7
112	2.20832	8.28E-30	.032	1099.341	0	28 28	0	29 28 28+		75	68	7
113	2.21160	4.45E-27	.032	1082.994	0	27 27	0	28 27 27+		75	66	7
114	2.21506	4.66E-30	.032	2477.495	1	25 25	1	26 25 25+		75	66	7
115	2.21674	5.90E-30	.032	1177.668	0	29 29	0	30 29 29+		75	68	7
116	2.22514	4.15E-30	.032	1258.667	0	30 30	0	31 30 30+		75	68	7
117	2.22943	2.20E-27	.032	1245.975	0	29 29	0	30 29 29+		75	66	7
118	2.24720	1.02E-27	.032	1420.255	0	31 31	0	32 31 31+		75	66	7
119	2.26492	4.48E-28	.032	1605.806	0	33 33	0	34 33 33+		75	66	7
120	2.28260	1.85E-28	.032	1802.598	0	35 35	0	36 35 35+		75	66	7
121	2.30026	7.24E-29	.032	2010.599	0	37 37	0	38 37 37+		75	66	7
122	2.31789	2.67E-29	.032	2229.774	0	39 39	0	40 39 39+		75	66	7
123	2.33551	9.29E-30	.032	2460.088	0	41 41	0	42 41 41+		75	66	7
124	3.96108	1.00E-25	.050	0.000	0	1 1	0	0 1 1+		75	66	7
125	3.96140	1.94E-28	.050	0.563	0	1 1	0	0 1 1+		75	68	7
126	3.97713	5.17E-29	.050	1556.378	1	1 1	1	0 1 1+		75	66	7
127	7.80360	2.91E-28	.050	0.000	0	1 2	0	1 0 8G		75	64	7
128	9.95599	1.67E-28	.050	0.000	0	2 2	0	1 0 8H		75	68	7
129	11.50856	4.25E-29	.048	4.525	0	2 3	0	1 1 8F		75	68	7
130	12.13118	1.14E-29	.048	1560.355	1	2 3	1	1 1 8F		75	66	7
131	12.29178	2.22E-26	.048	3.961	0	2 3	0	1 1 8F		75	66	7
132	13.40060	4.72E-28	.045	2.633	0	2 3	0	2 1 8G		75	68	7
133	14.02102	1.25E-28	.045	1558.465	1	2 3	1	2 1 8G		75	66	7
134	14.16858	2.43E-29	.045	2.084	0	2 3	0	2 1 8G		75	66	7
135	15.46998	2.05E-28	.045	2.633	0	3 3	0	2 1 8H		75	64	7
136	16.10831	5.38E-29	.045	1558.465	1	3 3	1	2 1 8H		75	66	7
137	16.25289	1.04E-25	.045	2.084	0	3 3	0	2 1 8H		75	66	7
138	16.97828	8.41E-29	.048	9.956	0	3 4	0	2 2 8F		75	68	7
139	18.90961	6.35E-28	.047	8.025	0	3 4	0	3 2 8G		75	68	7
140	20.93973	2.40E-28	.047	8.025	0	4 4	0	3 2 8H		75	68	7
141	22.43321	1.22E-28	.045	18.103	0	4 8	0	3 3 3F		75	68	7
142	23.57570	3.24E-29	.045	1574.574	1	4 8	1	3 3 8F		75	66	7
143	23.86295	6.28E-26	.045	18.337	0	4 8	0	3 3 8F		75	66	7
144	24.38978	7.75E-28	.044	16.146	0	4 5	0	4 3 8G		75	68	7

RIVERSIDE RESEARCH INSTITUTE

OXYGENEX-157 ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCHL FORMAT)

	FREQ	STRENGTH	WIDTH	E ₁	V ₁	J ₁ K ₁	V ₂	J ₂ K ₂	ID	DATE	ISO	NO
145	25.53774	2.05E-28	.044	1572.612	1	4 5	1	4 3	SG	75	66	7
146	25.81252	3.96E-25	.044	16.388	0	4 5	0	4 3	SG	75	66	7
147	26.39469	2.69E-28	.044	16.146	0	5 5	0	4 3	SH	75	68	7
148	27.55283	7.08E-29	.044	1572.612	1	5 5	1	4 3	SH	75	66	7
149	27.82411	1.37E-25	.044	16.388	0	5 5	0	4 3	SH	75	66	7
150	27.88090	1.53E-28	.044	28.964	0	5 6	0	4 4	SF	75	64	7
151	29.85639	8.87E-28	.043	26.989	0	5 6	0	5 4	SG	75	68	7
152	31.84241	2.92E-28	.043	26.989	0	6 6	0	5 4	SH	75	68	7
153	33.32407	1.78E-28	.043	42.541	0	6 7	0	5 5	SF	75	64	7
154	34.98245	4.71E-29	.043	1600.164	1	6 7	1	5 5	SF	75	66	7
155	35.31609	9.69E-28	.042	40.050	0	6 7	0	6 5	SG	75	64	7
156	35.39530	9.10E-26	.043	44.212	0	6 7	0	5 5	F	75	66	7
157	36.98309	2.55E-28	.042	1598.164	1	6 7	1	6 5	SG	75	66	7
158	37.28562	3.06E-28	.042	40.550	0	7 7	0	6 5	SH	75	68	7
159	37.38305	4.91E-25	.042	42.224	0	6 7	0	6 5	SG	75	66	7
160	38.76386	1.96E-28	.043	58.831	0	7 8	0	6 6	SF	75	68	7
161	38.95558	8.01E-29	.042	1598.164	1	7 7	1	6 5	SH	75	66	7
162	39.35655	1.54E-25	.042	42.224	0	7 7	0	6 5	SH	75	66	7
163	40.76842	1.02E-27	.041	56.827	0	7 8	0	7 6	SG	75	68	7
164	42.72546	3.13E-28	.041	56.827	0	8 8	0	7 6	SH	75	68	7
165	44.20080	2.07E-28	.042	77.835	0	8 9	0	7 7	SF	75	68	7
166	46.21758	1.04E-27	.041	75.419	0	8 9	0	8 7	SG	75	64	7
167	46.37341	5.40E-29	.042	1637.123	1	8 9	1	7 7	SF	75	66	7
168	46.91156	1.04E-25	.042	81.581	0	8 9	0	7 7	SF	75	66	7
169	48.16245	3.12E-28	.041	75.819	0	9 9	0	8 7	SH	75	68	7
170	48.40290	2.71E-28	.041	1635.094	1	8 9	1	8 7	SG	75	66	7
171	48.92745	5.22E-25	.041	79.565	0	8 9	0	8 7	SG	75	66	7
172	49.63509	2.11E-28	.042	99.552	0	9 10	0	8 8	SF	75	68	7
173	50.35054	8.09E-29	.041	1635.094	1	9 9	1	8 7	SH	75	66	7
174	50.87292	1.56E-25	.041	79.565	0	9 9	0	8 7	SH	75	66	7
175	51.66320	1.03E-27	.041	97.524	0	9 10	0	9 8	SG	75	68	7
176	53.59681	3.04E-28	.041	97.524	0	10 10	0	9 8	SH	75	68	7
177	55.06678	2.08E-28	.041	123.981	0	10 11	0	9 9	SF	75	68	7
178	57.10558	1.00E-27	.040	121.942	0	10 11	0	10 9	SG	75	68	7
179	57.75231	5.37E-29	.041	1685.444	1	10 11	1	9 9	SF	75	66	7
180	58.44563	1.03E-25	.041	130.438	0	10 11	0	9 9	SF	75	66	7
181	59.02856	2.90E-28	.040	121.942	0	11 11	0	10 9	SH	75	68	7
182	59.80650	2.58E-28	.040	1683.390	1	10 11	1	10 9	SG	75	66	7
183	60.45539	4.95E-25	.040	128.398	0	10 11	0	10 9	SG	75	66	7
184	60.49582	2.01E-28	.041	151.121	0	11 12	0	10 10	SF	75	68	7
185	61.72944	7.45E-29	.040	1683.390	1	11 11	1	10 9	SH	75	66	7
186	62.37713	1.43E-25	.040	128.398	0	11 11	0	10 9	SH	75	66	7
187	62.54486	9.49E-28	.039	149.072	0	11 12	0	11 10	SG	75	68	7
188	64.45768	2.72E-28	.039	149.072	0	12 12	0	11 10	SH	75	68	7
189	65.92213	1.89E-28	.041	180.971	0	12 13	0	11 11	SF	75	68	7
190	67.98106	8.82E-28	.039	178.912	0	12 13	0	12 11	SG	75	68	7
191	69.11929	4.80E-29	.041	1745.120	1	12 13	1	11 11	SF	75	66	7
192	69.88407	2.50E-28	.039	178.912	0	13 13	0	12 11	SH	75	68	7
193	69.90770	9.19E-26	.041	190.775	0	12 13	0	11 11	SF	75	66	7
194	71.19601	2.24E-28	.039	1743.043	1	12 13	1	12 11	SG	75	66	7

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OXYGEN-181 ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCHL FORMAT)

	FREQ	STRENGTH	WIDTH	E ₁	V ₁	J ₁	K ₁	V ₂	J ₂	K ₂	ID	DATE	ISO	NO
195	71.34558	1.74E-28	.040	213.530	0	13	14	0	12	12	SF	75	68	7
196	71.36913	4.28E-25	.039	188.714	0	12	13	0	12	11	SG	75	66	7
197	73.09642	6.32E-29	.039	1743.043	1	13	13	1	12	11	SH	75	66	7
198	73.41411	8.03E-28	.039	211.461	0	13	14	0	13	12	SG	75	68	7
199	73.86939	1.21E-25	.039	188.714	0	13	13	0	12	11	SH	75	66	7
200	75.30761	2.25E-28	.039	211.461	0	14	14	0	13	12	SH	75	68	7
201	76.76602	1.57E-28	.038	248.796	0	14	15	0	13	13	SF	75	64	7
202	74.84394	7.18E-28	.038	246.718	0	14	15	0	14	13	SG	75	64	7
203	80.47340	3.92E-29	.038	1816.139	1	14	15	1	13	13	SF	75	66	7
204	80.72815	2.00E-28	.038	246.718	0	15	15	0	14	13	SH	75	64	7
205	81.38685	7.48E-26	.038	262.583	0	14	15	0	13	13	SF	75	66	7
206	82.18328	1.39E-28	.038	286.769	0	15	16	0	14	14	SF	75	64	7
207	82.57138	1.79E-28	.038	1814.041	1	14	15	1	14	13	SG	75	66	7
208	83.46866	3.41E-25	.038	260.501	0	14	15	0	14	13	SG	75	66	7
209	84.27043	6.30E-28	.036	284.681	0	15	16	0	15	14	SG	75	64	7
210	84.45053	4.97E-29	.038	1814.041	1	15	15	1	14	13	SH	75	66	7
211	85.34874	9.46E-26	.038	260.501	0	15	15	0	14	13	SH	75	66	7
212	86.14551	1.74E-28	.036	284.681	0	16	16	0	15	14	SH	75	68	7
213	87.59720	1.21E-28	.036	327.446	0	16	17	0	15	15	SF	75	68	7
214	89.69343	5.44E-28	.034	325.150	0	16	17	0	16	15	SG	75	68	7
215	91.55954	1.49E-28	.034	325.150	0	17	17	0	16	15	SH	75	68	7
216	91.81322	2.96E-29	.036	1896.492	1	16	17	1	15	15	SF	75	66	7
217	92.85169	5.62E-26	.036	345.850	0	16	17	0	15	15	SF	75	66	7
218	93.00758	1.03E-28	.037	370.827	0	17	18	0	16	16	SF	75	68	7
219	93.93166	1.33E-28	.034	1896.373	1	16	17	1	16	15	SG	75	66	7
220	94.95307	2.52E-25	.034	343.748	0	16	17	0	16	15	SG	75	66	7
221	95.11278	4.61E-28	.035	368.722	0	17	18	0	17	16	SG	75	68	7
222	95.79085	3.65E-29	.034	1896.373	1	17	17	1	16	15	SH	75	66	7
223	96.81382	6.91E-26	.034	343.748	0	17	17	0	16	15	SH	75	66	7
224	96.97004	1.26E-28	.035	368.722	0	18	18	0	17	16	SH	75	68	7
225	98.41425	8.67E-29	.037	416.909	0	18	19	0	17	17	SF	75	68	7
226	100.52832	3.85E-28	.036	414.795	0	18	19	0	18	17	SG	75	68	7
227	102.37684	1.05E-28	.036	414.795	0	19	19	0	18	17	SH	75	68	7
228	103.13716	2.08E-29	.037	1992.164	1	18	19	1	17	17	SF	75	66	7
229	103.81702	7.16E-29	.037	465.692	0	19	20	0	18	18	SF	75	68	7
230	104.40063	3.92E-26	.037	440.562	0	18	19	0	17	17	SF	75	66	7
231	105.27552	9.23E-29	.036	1990.025	1	18	19	1	18	17	SG	75	66	7
232	105.93987	3.17E-28	.036	463.569	0	19	20	0	19	18	SG	75	68	7
233	106.42105	1.74E-25	.036	438.442	0	18	19	0	18	17	SG	75	66	7
234	107.11429	2.50E-29	.036	1990.025	1	19	19	1	18	17	SH	75	66	7
235	107.77973	8.56E-29	.036	463.569	0	20	20	0	19	18	SH	75	68	7
236	108.26304	4.72E-26	.036	438.442	0	19	19	0	18	17	SH	75	66	7
237	109.21568	5.82E-29	.036	517.172	0	20	21	0	19	19	SF	75	68	7
238	111.34725	2.56E-28	.035	515.041	0	20	21	0	20	19	SG	75	68	7
239	113.17852	6.90E-29	.035	515.041	0	21	21	0	20	19	SH	75	68	7
240	114.44353	1.36E-29	.036	2097.140	1	20	21	1	19	19	SF	75	66	7
241	114.61004	4.65E-29	.036	571.349	0	21	22	0	20	20	SF	75	68	7
242	115.73199	2.56E-26	.036	546.705	0	20	21	0	19	19	SF	75	66	7
243	116.60142	5.99E-29	.035	2094.982	1	20	21	1	20	19	SG	75	66	7
244	114.75028	2.04E-28	.035	569.208	0	21	22	0	21	20	SG	75	68	7

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OXYGENEXIST ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCHL FORM 1)

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	IO	DATE	ISO	NO
245	117.87106	1.12E-25	.035	544.566	0	20 21	0	20 19	SO	75	66	7
246	118.42066	1.61E-29	.035	2094.982	1	21 21	1	20 19	SH	75	66	7
247	118.57303	5.47E-29	.035	569.208	0	22 22	0	21 20	SH	75	68	7
248	119.69469	3.02E-26	.035	544.566	0	21 21	0	20 19	SH	75	66	7
249	119.99990	3.66E-29	.035	628.219	0	22 23	0	21 21	SF	75	68	7
250	122.14877	1.60E-28	.035	626.070	0	22 23	0	22 21	SG	75	68	7
251	123.96305	4.28E-29	.035	626.070	0	23 23	0	22 21	SH	75	68	7
252	125.38508	2.44E-29	.036	687.782	0	23 24	0	22 22	SF	75	68	7
253	125.73056	8.35E-30	.035	2213.402	1	22 23	1	21 21	SF	75	66	7
254	127.14400	1.56E-26	.035	664.261	0	22 23	0	21 21	SF	75	66	7
255	127.54252	1.24E-28	.034	685.624	0	23 24	0	23 22	SG	75	68	7
256	127.90771	3.64E-29	.035	2211.225	1	22 23	1	22 21	SO	75	66	7
257	129.30146	6.79E-26	.035	662.103	0	22 23	0	22 21	SO	75	66	7
258	129.34838	3.30E-29	.034	685.624	0	24 24	0	23 22	SH	75	68	7
259	129.70769	9.73E-30	.035	2211.225	1	23 23	1	22 21	SH	75	66	7
260	130.76535	2.17E-29	.035	750.033	0	24 25	0	23 23	SF	75	68	7
261	131.10704	1.81E-26	.035	662.103	0	23 23	0	22 21	SH	75	66	7
262	132.93134	9.41E-29	.032	747.867	0	24 25	0	24 23	SG	75	68	7
263	134.72882	2.50E-29	.032	747.867	0	25 25	0	24 23	SH	75	68	7
264	136.14053	1.63E-29	.034	814.972	0	25 26	0	24 24	SF	75	68	7
265	136.99647	4.80E-30	.035	2340.933	1	24 25	1	23 23	SF	75	66	7
266	138.31503	7.06E-29	.032	812.798	0	25 26	0	25 24	SG	75	68	7
267	138.53489	8.40E-27	.035	793.210	0	24 25	0	23 23	SF	75	66	7
268	139.19266	2.08E-29	.032	2338.737	1	24 25	1	24 23	SG	75	68	7
269	140.10417	1.47E-29	.032	812.798	0	26 26	0	25 24	SH	75	68	7
270	140.71053	3.86E-26	.032	791.034	0	24 25	0	24 23	SG	75	66	7
271	140.97360	5.53E-30	.032	2338.737	1	25 25	1	24 23	SH	75	66	7
272	141.51041	1.21E-29	.032	887.596	0	26 27	0	25 25	SF	75	68	7
273	142.49829	1.02E-26	.032	791.034	0	25 25	0	24 23	SH	75	66	7
274	143.69339	5.22E-29	.032	880.413	0	26 27	0	26 25	SO	75	68	7
275	145.47423	1.38E-29	.032	880.413	0	27 27	0	26 25	SH	75	68	7
276	146.87478	8.85E-30	.032	952.902	0	27 28	0	26 26	SF	75	68	7
277	149.06623	3.81E-29	.032	950.711	0	27 28	0	27 26	SO	75	68	7
278	149.90285	4.78E-27	.032	935.533	0	26 27	0	25 25	SF	75	66	7
279	150.45451	1.12E-29	.032	2477.495	1	26 27	1	26 25	SO	75	66	7
280	150.83879	1.01E-29	.032	950.711	0	28 28	0	27 26	SH	75	68	7
281	152.09653	2.06E-26	.032	931.339	0	26 27	0	26 25	SG	75	68	7
282	152.23345	6.37E-30	.032	1025.887	0	28 29	0	27 27	SF	75	68	7
283	153.86664	5.44E-27	.032	931.339	0	27 27	0	26 25	SH	75	66	7
284	154.43335	2.74E-29	.032	1023.688	0	28 29	0	28 27	SO	75	68	7
285	156.19765	7.21E-30	.032	1023.688	0	29 29	0	28 27	SH	75	68	7
286	157.58621	4.52E-30	.032	1101.549	0	29 30	0	28 28	SF	75	68	7
287	159.79453	1.94E-29	.032	1099.341	0	29 30	0	29 28	SO	75	68	7
288	161.24605	2.41E-27	.032	1085.206	0	28 29	0	27 27	SF	75	66	7
289	161.55061	5.10E-30	.032	1099.341	0	30 30	0	29 28	SH	75	68	7
290	161.69148	5.68E-30	.032	2627.478	1	28 29	1	28 27	SO	75	66	7
291	163.45765	1.03E-26	.032	1082.994	0	28 29	0	28 27	SO	75	66	7
292	165.14960	1.35E-29	.032	1177.668	0	30 31	0	30 29	SO	75	68	7
293	165.21027	2.72E-27	.032	1082.994	0	29 29	0	28 27	SH	75	66	7
294	170.49833	9.33E-30	.032	1258.667	0	31 32	0	31 30	SG	75	68	7

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OXYGEN-18 ABSORPTION LINE PARAMETERS FOR MOLECULAR OXYGEN ISOTOPES (AFCHL FORMAT)

	FREQ	STRENGTH	WIDTH	E''	V'	J' K'	V''	J'' K''	IO	DATE	ISO	MO
295	172.56267	1.15E-27	.032	1248.204	0	30 31	0	29 29	SF	75	66	7
296	174.79210	4.29E-27	.032	1245.975	0	30 31	0	30 29	SG	75	66	7
297	175.84053	6.34E-30	.032	1342.332	0	32 33	0	32 31	SG	75	66	7
298	176.52734	1.28E-27	.032	1245.975	0	31 31	0	30 29	SH	75	66	7
299	181.17599	4.25E-30	.032	1428.663	0	33 34	0	33 32	SG	75	66	7
300	183.85086	5.13E-28	.032	1422.502	0	32 33	0	31 31	SF	75	66	7
301	186.09807	2.18E-27	.032	1420.255	0	32 33	0	32 31	SG	75	66	7
302	187.81602	5.71E-28	.032	1420.255	0	33 33	0	32 31	SH	75	66	7
303	195.10879	2.17E-28	.032	1608.071	0	34 35	0	33 33	SF	75	66	7
304	197.37371	9.19E-28	.032	1605.806	0	34 35	0	34 33	SG	75	66	7
305	199.07447	2.40E-28	.032	1605.806	0	35 35	0	34 33	SH	75	66	7
306	206.33461	8.63E-29	.032	1804.881	0	36 37	0	35 35	SF	75	66	7
307	208.61722	3.65E-28	.032	1802.598	0	36 37	0	36 35	SG	75	66	7
308	210.30084	9.50E-29	.032	1802.598	0	37 37	0	36 35	SH	75	66	7
309	217.52647	3.25E-29	.032	2012.899	0	38 39	0	37 37	SF	75	66	7
310	219.82673	1.37E-28	.032	2010.599	0	38 39	0	38 37	SG	75	66	7
311	221.49328	3.56E-29	.032	2010.599	0	39 39	0	38 37	SH	75	66	7
312	228.68253	1.15E-29	.032	2232.092	0	40 41	0	39 39	SF	75	66	7
313	231.00042	4.86E-29	.032	2229.774	0	40 41	0	40 39	SG	75	66	7
314	232.64995	1.26E-29	.032	2229.774	0	41 41	0	40 39	SH	75	66	7
315	239.80093	3.88E-30	.032	2462.424	0	42 43	0	41 41	SF	75	66	7
316	242.13644	1.63E-29	.032	2460.088	0	42 43	0	42 41	SG	75	66	7
317	243.76899	4.21E-30	.032	2460.088	0	43 43	0	42 41	SH	75	66	7
318	253.23294	5.17E-30	.032	2701.504	0	44 45	0	44 43	SG	75	66	7

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