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TRANSITION PROBABILITIES AND FRANCK-CONDON FACTORS
FOR THE SECOND NEGATIVE BAND SYSTEM OF O_2^+

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Abstract. Transition probabilities for the second negative band system of O_2^+ are computed using the dipole transition moment presented by Wetmore et al. [1984]. Vibrational levels $v'' = 0 - 54$ of the $X^2\Pi_g$ ground state and $v' = 0 - 33$ of the excited $A^2\Pi_u$ state are included. Franck-Condon factors for ionization-excitation of O_2 ($X^3\Sigma_g^-; v = 0 - 25$) to $O_2^+(A^2\Pi_u; v' = 0 - 33)$ are also presented.

1. Introduction

The second negative band system of O_2^+ arises from the transition $A^2\Pi_u(v') \rightarrow X^2\Pi_g(v'')$. The excited electronic state $A^2\Pi_u$ can be populated by photoionization and electron impact ionization of O_2 and by fluorescent scattering of radiation by $O_2^+(X^2\Pi_g)$ in planetary and cometary atmospheres. The latter process is a source of excitation of high vibrational levels ($v > 5 - 7$) of ground state O_2^+ in the atmospheres of the terrestrial planets [Fox, 1985, 1986]. Recently, James et al. [1988] and Schappe et al. [1988] have investigated the production of the second negative band system by electron impact on O_2 . They have presented cross sections for production of specific bands within the system and for the system as a whole. Analysis of the emission spectrum requires Franck-Condon factors for the excitation-ionization of ground state O_2 to produce $O_2^+(A^2\Pi_u)$ and radiative transition probabilities for individual bands of the second negative system. Since transition probabilities were not available, both James et al. and Schappe et al. used Franck-Condon factors to compute the ratios of band intensities, a practice which is valid only if the transition moment is constant with internuclear distance. In addition, in computing the Franck-Condon factors, James et al. used a Morse potential, which is less accurate for high vibrational levels than a Rydberg-Klein-Rees (RKR) potential.

Several years ago, in connection with studies of the vibrational distribution of O_2^+ in the dayside ionospheres of the terrestrial planets [Fox, 1985; 1986], we computed transition probabilities of the second negative band sys-

tem, using the *ab initio* dipole transition moment of Wetmore et al. [1984]. Wetmore et al. [1984] presented absorption oscillator strengths for the bands involving the first eight vibrational levels of the ground and excited states, and lifetimes of the $O_2^+(A^2\Pi_u)$ state for $v' = 0 - 33$. The computed lifetimes agreed very well with the available measured values [Jeunehomme, 1966; Erman and Larsson, 1977; Fink and Welge, 1968]. We present here transition probabilities for vibrational levels $v'' = 0$ to 54 of the ground state $O_2^+(X^2\Pi_g)$ and $v' = 0$ to 33 of $O_2^+(A^2\Pi_u)$. We also present Franck-Condon factors for ionization-excitation of $O_2(X^3\Sigma_g^-; v = 0 - 25)$ to produce $O_2^+(A^2\Pi_u; v' = 0 - 33)$, a wider range of vibrational quantum numbers than previously available [Nicholls, 1965; Krupenie, 1972]. Many vibrational quanta are potentially important, because the equilibrium internuclear distance of the $O_2^+(A^2\Pi_u)$ potential curve is very different from those of the $O_2(X^3\Sigma_g^-)$ and $O_2^+(X^2\Pi_g)$ states. Hence a wide range of vibrational levels of the *A* state are populated in ionization or fluorescent scattering; the excited states then decay to an even wider range of vibrational levels of the ground state.

2. Calculations and Results

We have constructed vibrational wave functions for the $O_2^+(X^2\Pi_g)$, $O_2^+(A^2\Pi_u)$ and $O_2(X^3\Sigma_g^-)$ states by numerical integration of the radial equation of nuclear motion [cf. Wetmore et al. 1984]. Our potential curves for O_2^+ were adopted from the RKR values of Krupenie [1972] extended to larger internuclear distances using the asymptotic polarization term $-\frac{1}{2}\alpha R^{-4}$, where $\alpha = 5.28a_0^3$ is the polarizability of atomic oxygen. The potential curves for the ground state of O_2 were taken from Allison et al. [1982]. The Franck-Condon factors for ionization-excitation of $O_2(X^3\Sigma_g^-; v = 0 - 25)$ to $O_2^+(A^2\Pi_u; v' = 0 - 33)$ are presented in Tables 1a - 1c. Our values for ionization-excitation from $O_2(X^3\Sigma_g^-; v = 0)$ agree well with those presented by James et al. [1988].

Transition probabilities and band origins of the second negative system are given in Tables 2a - 2e for $O_2^+(A^2\Pi_u, v' = 0 - 33)$ and $O_2^+(X^2\Pi_g, v'' = 0 - 54)$. Vibrational levels of the *X* state with $v'' \geq 30$ lie above the lowest vibrational level of the *A* state, so some of the high vibrational levels of the *X* state decay radiatively to vibrational levels of the *A* state. The "reverse" $X \rightarrow A$

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TABLE 1a. Franck-Condon Factors for Ionization of $O_2(X^3\Sigma_g^-; v'' = 0 - 10)$ to $O_2^+(A^2\Pi_u; v')$

| v' | v'' | | | | | | | | | | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0 | 3.058(-3) | 2.087(-2) | 6.692(-2) | 1.344(-1) | 1.900(-1) | 2.016(-1) | 1.674(-1) | 1.117(-1) | 6.107(-2) | 2.778(-2) | 1.062(-2) |
| 1 | 1.291(-2) | 6.225(-2) | 1.258(-1) | 1.295(-1) | 5.880(-2) | 1.670(-2) | 2.929(-2) | 1.064(-1) | 1.541(-1) | 1.420(-1) | 9.572(-2) |
| 2 | 2.994(-2) | 9.849(-2) | 1.108(-1) | 3.397(-2) | 3.490(-3) | 6.622(-2) | 9.167(-2) | 3.378(-2) | 6.845(-4) | 5.173(-2) | 1.228(-1) |
| 3 | 5.071(-2) | 1.084(-1) | 5.246(-2) | 6.114(-4) | 5.785(-2) | 6.538(-2) | 5.169(-3) | 2.669(-2) | 8.182(-2) | 5.235(-2) | 1.651(-3) |
| 4 | 7.032(-2) | 9.103(-2) | 8.519(-3) | 3.121(-3) | 6.362(-2) | 5.861(-3) | 2.837(-2) | 6.533(-2) | 1.432(-2) | 1.325(-2) | 7.128(-2) |
| 5 | 8.489(-2) | 5.968(-2) | 1.400(-3) | 5.759(-2) | 2.210(-2) | 1.215(-2) | 5.691(-2) | 1.122(-2) | 1.865(-2) | 6.072(-2) | 1.702(-2) |
| 6 | 9.260(-2) | 2.923(-2) | 1.864(-2) | 5.033(-2) | 6.671(-5) | 4.365(-2) | 2.341(-2) | 8.473(-3) | 5.152(-2) | 1.097(-2) | 1.737(-2) |
| 7 | 9.356(-2) | 8.749(-3) | 3.863(-2) | 2.484(-2) | 1.225(-2) | 4.216(-2) | 3.341(-5) | 3.978(-2) | 1.927(-2) | 9.868(-3) | 4.793(-2) |
| 8 | 8.904(-2) | 4.194(-4) | 4.806(-2) | 4.809(-3) | 3.237(-2) | 1.728(-2) | 1.423(-2) | 3.508(-2) | 3.231(-4) | 3.957(-2) | 1.282(-2) |
| 9 | 8.075(-2) | 1.844(-3) | 4.485(-2) | 3.029(-4) | 3.859(-2) | 9.443(-4) | 3.283(-2) | 9.288(-3) | 1.959(-2) | 2.697(-2) | 2.758(-3) |
| 10 | 7.022(-2) | 8.815(-3) | 3.356(-2) | 7.765(-3) | 2.935(-2) | 3.803(-3) | 3.154(-2) | 2.259(-4) | 3.303(-2) | 2.801(-3) | 2.581(-2) |
| 11 | 5.888(-2) | 1.723(-2) | 2.036(-2) | 1.851(-2) | 1.473(-2) | 1.579(-2) | 1.655(-2) | 1.059(-2) | 2.267(-2) | 3.792(-3) | 2.979(-2) |
| 12 | 4.824(-2) | 2.441(-2) | 9.733(-3) | 2.610(-2) | 3.990(-3) | 2.455(-2) | 3.691(-3) | 2.224(-2) | 6.376(-3) | 1.806(-2) | 1.290(-2) |
| 13 | 3.894(-2) | 2.926(-2) | 3.170(-3) | 2.850(-2) | 6.031(-5) | 2.554(-2) | 3.644(-5) | 2.430(-2) | 3.757(-6) | 2.427(-2) | 7.691(-4) |
| 14 | 3.103(-2) | 3.155(-2) | 3.465(-4) | 2.643(-2) | 1.494(-3) | 2.052(-2) | 3.618(-3) | 1.800(-2) | 3.894(-3) | 1.859(-2) | 2.514(-3) |
| 15 | 2.461(-2) | 3.180(-2) | 1.677(-4) | 2.188(-2) | 5.441(-3) | 1.338(-2) | 9.482(-3) | 9.455(-3) | 1.094(-2) | 8.826(-3) | 1.052(-2) |
| 16 | 1.944(-2) | 3.051(-2) | 1.453(-3) | 1.654(-2) | 9.533(-3) | 7.007(-3) | 1.396(-2) | 3.089(-3) | 1.549(-2) | 1.968(-3) | 1.596(-2) |
| 17 | 1.537(-2) | 2.830(-2) | 3.283(-3) | 1.160(-2) | 1.251(-2) | 2.721(-3) | 1.574(-2) | 2.672(-4) | 1.601(-2) | 2.729(-6) | 1.604(-2) |
| 18 | 1.217(-2) | 2.562(-2) | 5.068(-3) | 7.586(-3) | 1.399(-2) | 2.721(-3) | 1.512(-2) | 2.776(-4) | 1.356(-2) | 1.490(-3) | 1.241(-2) |
| 19 | 9.660(-3) | 2.275(-2) | 6.496(-3) | 4.622(-3) | 1.415(-2) | 8.599(-9) | 1.302(-2) | 1.770(-3) | 9.876(-3) | 4.200(-3) | 7.732(-3) |
| 20 | 7.697(-3) | 1.993(-2) | 7.456(-3) | 2.605(-3) | 1.337(-2) | 3.647(-4) | 1.035(-2) | 3.602(-3) | 6.321(-3) | 6.556(-3) | 3.849(-3) |
| 21 | 6.158(-3) | 1.727(-2) | 7.953(-3) | 1.333(-3) | 1.203(-2) | 1.118(-3) | 7.729(-3) | 5.103(-3) | 3.556(-3) | 7.896(-3) | 1.400(-3) |
| 22 | 4.941(-3) | 1.484(-2) | 8.043(-3) | 5.954(-4) | 1.045(-2) | 1.903(-3) | 5.490(-3) | 6.012(-3) | 1.716(-3) | 8.196(-3) | 2.590(-4) |
| 23 | 3.973(-3) | 1.263(-2) | 7.808(-3) | 2.125(-4) | 8.835(-3) | 2.527(-3) | 3.739(-3) | 6.327(-3) | 6.649(-4) | 7.727(-3) | 1.219(-6) |
| 24 | 3.198(-3) | 1.067(-2) | 7.333(-3) | 4.675(-5) | 7.317(-3) | 2.916(-3) | 2.457(-3) | 6.174(-3) | 1.694(-4) | 6.820(-3) | 1.991(-4) |
| 25 | 2.572(-3) | 8.944(-3) | 6.696(-3) | 8.700(-7) | 5.962(-3) | 3.070(-3) | 1.567(-3) | 5.705(-3) | 9.462(-6) | 5.743(-3) | 5.420(-4) |
| 26 | 2.064(-3) | 7.424(-3) | 5.961(-3) | 1.147(-5) | 4.793(-3) | 3.024(-3) | 9.738(-4) | 5.058(-3) | 1.831(-5) | 4.672(-3) | 8.512(-4) |
| 27 | 1.648(-3) | 6.096(-3) | 5.180(-3) | 4.056(-5) | 3.806(-3) | 2.827(-3) | 5.925(-4) | 4.337(-3) | 8.813(-5) | 3.702(-3) | 1.049(-3) |
| 28 | 1.305(-3) | 4.942(-3) | 4.395(-3) | 6.791(-5) | 2.987(-3) | 2.530(-3) | 3.549(-4) | 3.615(-3) | 1.592(-4) | 2.875(-3) | 1.122(-3) |
| 29 | 1.023(-3) | 3.946(-3) | 3.640(-3) | 8.500(-5) | 2.316(-3) | 2.179(-3) | 2.105(-4) | 2.938(-3) | 2.056(-4) | 2.195(-3) | 1.090(-3) |
| 30 | 7.917(-4) | 3.099(-3) | 2.941(-3) | 9.030(-5) | 1.771(-3) | 1.812(-3) | 1.245(-4) | 2.331(-3) | 2.216(-4) | 1.652(-3) | 9.854(-4) |
| 31 | 6.033(-4) | 2.389(-3) | 2.318(-3) | 8.597(-5) | 1.336(-3) | 1.458(-3) | 7.400(-5) | 1.808(-3) | 2.125(-4) | 1.226(-3) | 8.409(-4) |
| 32 | 4.522(-4) | 1.807(-3) | 1.783(-3) | 7.549(-5) | 9.922(-4) | 1.139(-3) | 4.446(-5) | 1.371(-3) | 1.873(-4) | 8.975(-4) | 6.843(-4) |
| 33 | 3.331(-4) | 1.339(-3) | 1.338(-3) | 6.224(-5) | 7.253(-4) | 8.643(-4) | 2.712(-5) | 1.018(-3) | 1.547(-4) | 6.483(-4) | 5.347(-4) |

Read 3.058(-3) as 3.058×10^{-3} .

TABLE 1b. Franck-Condon Factors for Ionization of $O_2(X^3\Sigma_g^-; v'' = 11 - 21)$ to $O_2^+(A^2\Pi_u; v')$

| v' | v'' | | | | | | | | | | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 0 | 3.438(-3) | 9.476(-4) | 2.229(-4) | 4.479(-5) | 7.679(-6) | 1.118(-6) | 1.378(-7) | 1.420(-8) | 1.199(-9) | 8.528(-11) | 4.381(-12) |
| 1 | 5.020(-2) | 2.119(-2) | 7.343(-3) | 2.115(-3) | 5.100(-4) | 1.032(-4) | 1.751(-5) | 2.481(-6) | 2.917(-7) | 2.786(-8) | 2.180(-9) |
| 2 | 1.424(-1) | 1.098(-1) | 6.264(-2) | 2.788(-2) | 9.966(-3) | 2.906(-3) | 6.979(-4) | 1.384(-4) | 2.262(-5) | 3.034(-6) | 3.280(-7) |
| 3 | 2.973(-2) | 1.030(-1) | 1.374(-1) | 1.138(-1) | 6.747(-2) | 3.055(-2) | 1.092(-2) | 3.136(-3) | 7.308(-4) | 1.383(-4) | 2.120(-5) |
| 4 | 5.735(-2) | 4.217(-3) | 2.258(-2) | 9.485(-2) | 1.338(-1) | 1.130(-1) | 6.708(-2) | 2.996(-2) | 1.043(-2) | 2.878(-3) | 6.338(-4) |
| 5 | 9.973(-3) | 6.637(-2) | 5.592(-2) | 4.134(-3) | 2.284(-2) | 9.507(-2) | 1.322(-1) | 1.093(-1) | 6.298(-2) | 2.703(-2) | 8.937(-3) |
| 6 | 5.711(-2) | 1.483(-2) | 1.130(-2) | 6.578(-2) | 5.081(-2) | 2.165(-3) | 2.834(-2) | 1.011(-1) | 1.317(-1) | 1.031(-1) | 5.610(-2) |
| 7 | 7.541(-3) | 2.058(-2) | 5.387(-2) | 9.950(-3) | 1.606(-2) | 6.721(-2) | 4.263(-2) | 2.269(-4) | 3.893(-2) | 1.110(-1) | 1.304(-1) |
| 8 | 1.436(-2) | 4.417(-2) | 3.260(-3) | 2.684(-2) | 4.928(-2) | 4.444(-3) | 2.425(-2) | 6.821(-2) | 3.168(-2) | 8.008(-4) | 5.491(-2) |
| 9 | 3.923(-2) | 6.131(-3) | 2.119(-2) | 3.844(-2) | 3.255(-4) | 3.483(-2) | 4.195(-2) | 5.703(-4) | 3.551(-2) | 6.619(-2) | 1.905(-2) |
| 10 | 1.756(-2) | 8.151(-3) | 3.633(-2) | 1.297(-3) | 2.888(-2) | 2.997(-2) | 7.314(-4) | 4.235(-2) | 3.158(-2) | 6.872(-4) | 4.803(-2) |
| 11 | 2.500(-5) | 2.999(-2) | 8.640(-3) | 1.551(-2) | 3.012(-2) | 9.363(-5) | 3.503(-2) | 1.984(-2) | 5.327(-3) | 4.684(-2) | 1.333(-2) |
| 12 | 1.043(-2) | 2.304(-2) | 1.717(-3) | 3.045(-2) | 2.439(-3) | 2.281(-2) | 2.179(-2) | 2.928(-3) | 3.788(-2) | 1.039(-2) | 1.977(-2) |
| 13 | 2.306(-2) | 4.846(-3) | 1.739(-2) | 1.473(-2) | 6.728(-3) | 2.723(-2) | 2.649(-5) | 2.821(-2) | 1.315(-2) | 8.884(-3) | 3.694(-2) |
| 14 | 2.116(-2) | 4.894(-4) | 2.362(-2) | 5.742(-4) | 2.208(-2) | 7.259(-3) | 1.298(-2) | 2.137(-2) | 1.328(-3) | 3.042(-2) | 5.994(-3) |
| 15 | 1.069(-2) | 8.213(-3) | 1.482(-2) | 4.116(-3) | 2.031(-2) | 3.309(-4) | 2.356(-2) | 2.247(-3) | 1.858(-2) | 1.461(-2) | 5.310(-3) |
| 16 | 2.263(-3) | 1.561(-2) | 4.033(-3) | 1.361(-2) | 8.147(-3) | 9.080(-3) | 1.503(-2) | 2.907(-3) | 2.209(-2) | 1.200(-4) | 2.227(-2) |
| 17 | 3.230(-5) | 1.656(-2) | 7.085(-6) | 1.714(-2) | 5.593(-4) | 1.663(-2) | 3.235(-3) | 1.337(-2) | 9.638(-3) | 6.748(-3) | 1.871(-2) |
| 18 | 2.283(-3) | 1.244(-2) | 2.187(-3) | 1.361(-2) | 1.233(-3) | 1.552(-2) | 1.259(-4) | 1.707(-2) | 6.510(-4) | 1.608(-2) | 5.246(-3) |
| 19 | 5.780(-3) | 6.976(-3) | 6.335(-3) | 7.498(-3) | 5.752(-3) | 9.315(-3) | 3.985(-3) | 1.234(-2) | 1.528(-3) | 1.570(-2) | 3.514(-6) |
| 20 | 8.355(-3) | 2.766(-3) | 9.292(-3) | 2.655(-3) | 9.460(-3) | 3.468(-3) | 8.678(-3) | 5.491(-3) | 6.697(-3) | 8.982(-3) | 3.596(-3) |
| 21 | 9.324(-3) | 5.651(-4) | 1.010(-2) | 3.437(-4) | 1.057(-2) | 4.734(-4) | 1.073(-2) | 1.125(-3) | 1.028(-2) | 2.824(-3) | 8.671(-3) |
| 22 | 8.928(-3) | 1.188(-7) | 9.199(-3) | 7.624(-5) | 9.498(-3) | 8.835(-5) | 9.981(-3) | 4.759(-6) | 1.054(-2) | 1.666(-4) | 1.073(-2) |
| 23 | 7.723(-3) | 3.564(-4) | 7.436(-3) | 8.460(-4) | 7.368(-3) | 1.060(-3) | 7.722(-3) | 8.634(-4) | 8.543(-3) | 3.788(-4) | 9.631(-3) |
| 24 | 6.224(-3) | 1.024(-3) | 5.516(-3) | 1.832(-3) | 5.125(-3) | 2.289(-3) | 5.212(-3) | 2.263(-3) | 5.856(-3) | 1.768(-3) | 7.031(-3) |
| 25 | 4.769(-3) | 1.631(-3) | 3.836(-3) | 2.589(-3) | 3.268(-3) | 3.188(-3) | 3.143(-3) | 3.354(-3) | 3.506(-3) | 3.086(-3) | 4.391(-3) |
| 26 | 3.522(-3) | 2.020(-3) | 2.539(-3) | 2.976(-3) | 1.935(-3) | 3.594(-3) | 1.710(-3) | 3.869(-3) | 1.854(-3) | 3.823(-3) | 2.397(-3) |
| 27 | 2.535(-3) | 2.165(-3) | 1.619(-3) | 3.021(-3) | 1.074(-3) | 3.572(-3) | 8.390(-4) | 3.867(-3) | 8.617(-4) | 3.956(-3) | 1.146(-3) |
| 28 | 1.792(-3) | 2.109(-3) | 1.005(-3) | 2.819(-3) | 5.611(-4) | 3.265(-3) | 3.667(-4) | 3.524(-3) | 3.428(-4) | 3.666(-3) | 4.708(-4) |
| 29 | 1.253(-3) | 1.916(-3) | 6.130(-4) | 2.475(-3) | 2.773(-4) | 2.810(-3) | 1.386(-4) | 3.012(-3) | 1.089(-4) | 3.156(-3) | 1.575(-4) |
| 30 | 8.699(-4) | 1.649(-3) | 3.710(-4) | 2.070(-3) | 1.302(-4) | 2.310(-3) | 4.229(-5) | 2.455(-3) | 2.267(-5) | 2.577(-3) | 3.681(-5) |
| 31 | 6.016(-4) | 1.356(-3) | 2.246(-4) | 1.665(-3) | 5.846(-5) | 1.831(-3) | 8.635(-6) | 1.929(-3) | 1.047(-6) | 2.023(-3) | 3.113(-6) |
| 32 | 4.152(-4) | 1.073(-3) | 1.371(-4) | 1.296(-3) | 2.529(-5) | 1.407(-3) | 4.562(-7) | 1.471(-3) | 1.554(-6) | 1.539(-3) | 7.709(-7) |
| 33 | 2.558(-4) | 8.220(-4) | 8.478(-5) | 9.791(-4) | 1.067(-5) | 1.053(-3) | 4.203(-7) | 1.094(-3) | 6.087(-6) | 1.142(-3) | 5.430(-6) |

TABLE 1c. Franck-Condon Factors for Ionization of $O_2(X^3\Sigma_g^-; v'' = 22 - 25)$ to $O_2^+(A^2\Pi_u; v')$

| v' | v'' | | | |
|------|------------|------------|------------|------------|
| | 22 | 23 | 24 | 25 |
| 0 | 1.734(-13) | 1.402(-14) | 1.358(-15) | 1.458(-15) |
| 1 | 1.301(-10) | 5.255(-12) | 3.902(-13) | 2.301(-14) |
| 2 | 2.842(-8) | 1.915(-9) | 8.125(-11) | 5.250(-12) |
| 3 | 2.597(-6) | 2.497(-7) | 1.865(-8) | 9.033(-10) |
| 4 | 1.114(-4) | 1.547(-5) | 1.660(-6) | 1.365(-7) |
| 5 | 2.308(-3) | 4.675(-4) | 7.378(-5) | 8.873(-6) |
| 6 | 2.258(-2) | 6.909(-3) | 1.624(-3) | 2.926(-4) |
| 7 | 9.406(-2) | 4.720(-2) | 1.737(-2) | 4.786(-3) |
| 8 | 1.224(-1) | 1.266(-1) | 8.221(-2) | 3.720(-2) |
| 9 | 6.715(-3) | 7.602(-2) | 1.330(-1) | 1.193(-1) |
| 10 | 5.900(-2) | 7.356(-3) | 2.053(-2) | 1.016(-1) |
| 11 | 6.192(-3) | 5.850(-2) | 4.635(-2) | 4.604(-4) |
| 12 | 4.703(-2) | 9.229(-3) | 1.657(-2) | 6.410(-2) |
| 13 | 3.429(-3) | 2.321(-2) | 4.265(-2) | 1.985(-3) |
| 14 | 1.634(-2) | 3.251(-2) | 1.707(-4) | 3.272(-2) |
| 15 | 2.951(-2) | 1.487(-3) | 2.373(-2) | 2.542(-2) |
| 16 | 8.420(-3) | 1.061(-2) | 2.612(-2) | 1.064(-7) |
| 17 | 4.815(-4) | 2.378(-2) | 3.776(-3) | 1.602(-2) |
| 18 | 1.057(-2) | 1.456(-2) | 2.530(-3) | 2.333(-2) |
| 19 | 1.708(-2) | 2.260(-3) | 1.369(-2) | 1.046(-2) |
| 20 | 1.343(-2) | 6.014(-4) | 1.683(-2) | 6.189(-4) |
| 21 | 6.132(-3) | 5.578(-3) | 1.097(-2) | 1.808(-3) |
| 22 | 1.245(-3) | 9.781(-3) | 4.001(-3) | 7.144(-3) |
| 23 | 6.771(-6) | 1.044(-2) | 4.421(-4) | 1.021(-2) |
| 24 | 9.526(-4) | 8.500(-3) | 1.820(-4) | 9.795(-3) |
| 25 | 2.404(-3) | 5.760(-3) | 1.414(-3) | 7.443(-3) |
| 26 | 3.440(-3) | 3.381(-3) | 2.696(-3) | 4.808(-3) |
| 27 | 3.830(-3) | 1.747(-3) | 3.422(-3) | 2.736(-3) |
| 28 | 3.697(-3) | 7.957(-4) | 3.551(-3) | 1.396(-3) |
| 29 | 3.259(-3) | 3.133(-4) | 3.269(-3) | 6.430(-4) |
| 30 | 2.698(-3) | 1.015(-4) | 2.780(-3) | 2.668(-4) |
| 31 | 2.134(-3) | 2.358(-5) | 2.238(-3) | 9.849(-5) |
| 32 | 1.631(-3) | 2.278(-6) | 1.731(-3) | 3.133(-5) |
| 33 | 1.213(-3) | 2.267(-7) | 1.296(-3) | 7.972(-6) |

transitions are indicated by negative band origins and transition probabilities. For strong bands with fairly low vibrational quantum number, intensity ratios computed with our transition probabilities agree to within a few percent with those computed with the Franck-Condon factors of James et al. [1988] and Schappe et al. [1988]. Significant differences arise for weaker bands and higher vibrational levels.

TABLE 2a. Transition Probabilities (s^{-1}) (Upper Entry) and Band Origins (nm) (Lower Entry) of the Second Negative Band System of $O_2^+(A; v' \rightarrow X; v'' = 0 - 10)$

| v' | v'' | | | | | | | | | | |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0 | 7.400(0) | 1.238(2) | 9.789(2) | 4.867(3) | 1.707(4) | 4.487(4) | 9.179(4) | 1.497(5) | 1.990(5) | 2.210(5) | 2.069(5) |
| | 249.56 | 261.80 | 275.05 | 289.43 | 305.11 | 322.24 | 341.03 | 361.74 | 384.70 | 410.25 | 438.67 |
| 1 | 6.164(1) | 8.958(2) | 6.021(3) | 2.474(4) | 6.913(4) | 1.376(5) | 1.979(5) | 2.017(5) | 1.353(5) | 4.590(4) | 5.126(2) |
| | 244.25 | 255.96 | 268.61 | 282.32 | 297.21 | 313.44 | 331.19 | 350.69 | 372.23 | 396.10 | 422.53 |
| 2 | 2.736(2) | 3.453(3) | 1.967(4) | 6.621(4) | 1.444(5) | 2.077(5) | 1.879(5) | 8.728(4) | 5.956(3) | 2.124(4) | 8.561(4) |
| | 239.32 | 250.55 | 262.66 | 275.75 | 289.94 | 305.36 | 322.19 | 340.61 | 360.89 | 383.29 | 407.99 |
| 3 | 8.608(2) | 9.436(3) | 4.535(4) | 1.236(5) | 2.042(5) | 1.961(5) | 8.541(4) | 1.885(3) | 3.827(4) | 9.808(4) | 6.650(4) |
| | 234.73 | 245.53 | 257.14 | 269.68 | 283.23 | 297.94 | 313.93 | 331.40 | 350.56 | 371.65 | 394.83 |
| 4 | 2.155(3) | 2.051(4) | 8.279(4) | 1.800(5) | 2.154(5) | 1.180(5) | 7.607(3) | 3.332(4) | 1.001(5) | 5.931(4) | 4.857(2) |
| | 230.46 | 240.86 | 252.03 | 264.05 | 277.04 | 291.09 | 306.34 | 322.95 | 341.12 | 361.06 | 382.89 |
| 5 | 4.570(3) | 3.774(4) | 1.272(5) | 2.161(5) | 1.743(5) | 3.624(4) | 1.249(4) | 9.408(4) | 7.345(4) | 2.056(3) | 3.712(4) |
| | 226.48 | 236.51 | 247.28 | 258.84 | 271.31 | 284.77 | 299.35 | 315.19 | 332.47 | 351.39 | 372.04 |
| 6 | 8.528(3) | 6.108(4) | 1.707(5) | 2.203(5) | 1.052(5) | 4.608(2) | 6.506(4) | 9.753(4) | 1.449(4) | 2.205(4) | 7.010(4) |
| | 222.78 | 232.47 | 242.86 | 254.01 | 266.00 | 278.93 | 292.90 | 308.05 | 324.54 | 342.54 | 362.13 |
| 7 | 1.436(4) | 8.918(4) | 2.049(5) | 1.930(5) | 4.114(4) | 1.700(4) | 1.029(5) | 5.055(4) | 3.050(3) | 6.470(4) | 3.748(4) |
| | 219.31 | 228.71 | 238.75 | 249.52 | 261.08 | 273.53 | 286.95 | 301.47 | 317.25 | 334.43 | 353.08 |

| | | | | | | | | | | | |
|----|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 8 | 2.222(4) | 1.196(5) | 2.235(5) | 1.448(5) | 5.139(3) | 5.924(4) | 9.689(4) | 7.834(3) | 3.722(4) | 6.367(4) | 2.108(3) |
| | 216.09 | 225.20 | 234.93 | 245.35 | 256.52 | 268.52 | 281.45 | 295.41 | 310.54 | 326.98 | 344.78 |
| 9 | 3.196(4) | 1.490(5) | 2.237(5) | 9.063(4) | 2.755(3) | 9.469(4) | 5.952(4) | 2.804(3) | 6.821(4) | 2.812(4) | 1.042(4) |
| | 213.08 | 221.93 | 231.38 | 241.48 | 252.29 | 263.89 | 276.36 | 289.81 | 304.36 | 320.13 | 337.18 |
| 10 | 4.300(4) | 1.736(5) | 2.064(5) | 4.401(4) | 2.467(4) | 1.046(5) | 2.051(4) | 2.789(4) | 6.616(4) | 2.000(3) | 3.946(4) |
| | 210.28 | 218.89 | 228.08 | 237.89 | 248.37 | 259.61 | 271.67 | 284.65 | 298.68 | 313.85 | 330.22 |
| 11 | 5.428(4) | 1.901(5) | 1.759(5) | 1.354(4) | 5.473(4) | 8.897(4) | 1.142(3) | 5.586(4) | 3.943(4) | 5.461(3) | 5.104(4) |
| | 207.69 | 216.09 | 225.04 | 234.58 | 244.77 | 255.68 | 267.37 | 279.93 | 293.48 | 308.13 | 323.89 |
| 12 | 6.507(4) | 1.981(5) | 1.400(5) | 8.530(2) | 7.940(4) | 6.054(4) | 4.220(3) | 6.752(4) | 1.250(4) | 2.589(4) | 3.802(4) |
| | 205.31 | 213.52 | 222.25 | 231.56 | 241.48 | 252.09 | 263.44 | 275.64 | 288.76 | 302.93 | 318.15 |
| 13 | 7.479(4) | 1.985(5) | 1.044(5) | 2.207(3) | 9.224(4) | 3.227(4) | 2.041(4) | 6.065(4) | 3.973(2) | 4.301(4) | 1.662(4) |
| | 203.13 | 211.17 | 219.70 | 228.79 | 238.47 | 248.81 | 259.87 | 271.72 | 284.47 | 298.21 | 312.94 |
| 14 | 8.263(4) | 1.917(5) | 7.284(4) | 1.203(4) | 9.246(4) | 1.193(4) | 3.843(4) | 4.291(4) | 3.754(3) | 4.662(4) | 2.533(3) |
| | 201.14 | 209.01 | 217.37 | 226.26 | 235.73 | 245.82 | 256.61 | 268.16 | 280.57 | 293.93 | 308.24 |
| 15 | 8.854(4) | 1.803(5) | 4.746(4) | 2.510(4) | 8.352(4) | 1.815(3) | 5.102(4) | 2.394(4) | 1.527(4) | 3.847(4) | 5.540(2) |
| | 199.32 | 207.05 | 215.25 | 223.96 | 233.23 | 243.11 | 253.65 | 264.94 | 277.04 | 290.05 | 303.98 |
| 16 | 9.216(4) | 1.653(5) | 2.852(4) | 3.755(4) | 6.938(4) | 2.505(2) | 5.564(4) | 9.657(3) | 2.713(4) | 2.517(4) | 6.892(3) |
| | 197.66 | 205.26 | 213.31 | 221.87 | 230.96 | 240.65 | 250.98 | 262.02 | 273.85 | 286.56 | 300.14 |
| 17 | 9.371(4) | 1.488(5) | 1.551(4) | 4.729(4) | 5.386(4) | 4.081(3) | 5.337(4) | 1.987(3) | 3.478(4) | 1.283(4) | 1.552(4) |
| | 196.16 | 203.63 | 211.56 | 219.97 | 228.91 | 238.42 | 248.55 | 259.38 | 270.97 | 283.40 | 296.68 |
| 18 | 9.331(4) | 1.319(5) | 7.314(3) | 5.348(4) | 3.940(4) | 1.023(4) | 4.665(4) | 5.961(0) | 3.707(4) | 4.520(3) | 2.216(4) |
| | 194.79 | 202.17 | 209.98 | 218.26 | 227.06 | 236.41 | 246.37 | 257.00 | 268.38 | 280.57 | 293.58 |
| 19 | 9.112(4) | 1.152(5) | 2.710(3) | 5.615(4) | 2.727(4) | 1.642(4) | 3.792(4) | 1.679(3) | 3.495(4) | 6.301(2) | 2.512(4) |
| | 193.57 | 200.85 | 208.55 | 216.72 | 225.39 | 234.60 | 244.41 | 254.87 | 266.05 | 278.03 | 290.80 |
| 20 | 8.748(4) | 9.960(4) | 5.805(2) | 5.590(4) | 1.790(4) | 2.137(4) | 2.910(4) | 4.995(3) | 3.020(4) | 1.116(2) | 2.472(4) |
| | 192.46 | 199.66 | 207.27 | 215.34 | 223.90 | 232.99 | 242.66 | 252.96 | 263.98 | 275.76 | 288.32 |
| 21 | 8.269(4) | 8.533(4) | 1.740(0) | 5.348(4) | 1.113(4) | 2.457(4) | 2.128(4) | 8.483(3) | 2.444(4) | 1.511(3) | 2.206(4) |
| | 191.48 | 198.60 | 206.13 | 214.11 | 222.57 | 231.55 | 241.09 | 251.26 | 262.13 | 273.74 | 286.12 |
| 22 | 7.695(4) | 7.249(4) | 2.788(2) | 4.956(4) | 6.515(3) | 2.598(4) | 1.493(4) | 1.129(4) | 1.878(4) | 3.591(3) | 1.833(4) |
| | 190.61 | 197.66 | 205.12 | 213.02 | 221.39 | 230.27 | 239.71 | 249.76 | 260.49 | 271.96 | 284.17 |
| 23 | 7.052(4) | 6.109(4) | 9.265(2) | 4.475(4) | 3.554(3) | 2.588(4) | 1.009(4) | 1.307(4) | 1.384(4) | 5.536(3) | 1.443(4) |
| | 189.84 | 196.83 | 204.23 | 212.06 | 220.35 | 229.15 | 238.49 | 248.44 | 259.06 | 270.40 | 282.46 |
| 24 | 6.364(4) | 5.108(4) | 1.633(3) | 3.953(4) | 1.775(3) | 2.462(4) | 6.603(3) | 1.381(4) | 9.868(3) | 6.937(3) | 1.090(4) |
| | 189.16 | 196.11 | 203.45 | 211.22 | 219.44 | 228.17 | 237.43 | 247.29 | 257.80 | 269.03 | 280.97 |
| 25 | 5.653(4) | 4.238(4) | 2.218(3) | 3.426(4) | 7.860(2) | 2.258(4) | 4.196(3) | 1.365(4) | 6.856(3) | 7.671(3) | 7.953(3) |
| | 188.58 | 195.48 | 202.77 | 210.49 | 218.66 | 227.32 | 236.51 | 246.29 | 256.72 | 267.85 | 279.69 |
| 26 | 4.938(4) | 3.485(4) | 2.599(3) | 2.917(4) | 2.886(2) | 2.009(4) | 2.599(3) | 1.284(4) | 4.667(3) | 7.790(3) | 5.708(3) |
| | 188.08 | 194.94 | 202.20 | 209.87 | 217.99 | 226.59 | 235.73 | 245.44 | 255.79 | 266.85 | 278.59 |
| 27 | 4.236(4) | 2.837(4) | 2.757(3) | 2.441(4) | 7.431(1) | 1.738(4) | 1.575(3) | 1.158(4) | 3.131(3) | 7.422(3) | 4.013(3) |
| | 187.66 | 194.49 | 201.71 | 209.34 | 217.42 | 225.98 | 235.06 | 244.72 | 255.01 | 265.99 | 277.66 |
| 28 | 3.563(4) | 2.282(4) | 2.714(3) | 2.006(4) | 6.457(0) | 1.467(4) | 9.378(2) | 1.007(4) | 2.080(3) | 6.721(3) | 2.789(3) |
| | 187.30 | 194.11 | 201.30 | 208.90 | 216.94 | 225.46 | 234.51 | 244.12 | 254.36 | 265.29 | 276.89 |

TABLE 2a. (continued)

| v' | v'' | | | | | | | | | | |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 29 | 2.933(4) | 1.810(4) | 2.513(3) | 1.618(4) | 2.672(0) | 1.207(4) | 5.523(2) | 8.484(3) | 1.375(3) | 5.829(3) | 1.924(3) |
| | 187.01 | 193.80 | 200.97 | 208.54 | 216.56 | 225.05 | 234.05 | 243.63 | 253.83 | 264.71 | 276.26 |
| 30 | 2.361(4) | 1.413(4) | 2.209(3) | 1.280(4) | 1.831(1) | 9.692(3) | 3.238(2) | 6.933(3) | 9.082(2) | 4.867(3) | 1.322(3) |
| | 186.78 | 193.55 | 200.70 | 208.25 | 216.24 | 224.71 | 233.69 | 243.23 | 253.40 | 264.24 | 275.75 |
| 31 | 1.856(4) | 1.084(4) | 1.855(3) | 9.916(3) | 3.297(1) | 7.597(3) | 1.905(2) | 5.506(3) | 6.013(2) | 3.926(3) | 9.073(2) |
| | 186.60 | 193.35 | 200.48 | 208.02 | 216.00 | 224.44 | 233.40 | 242.92 | 253.06 | 263.87 | 275.35 |
| 32 | 1.425(4) | 8.168(3) | 1.495(3) | 7.525(3) | 4.017(1) | 5.815(3) | 1.132(2) | 4.255(3) | 3.998(2) | 3.069(3) | 6.223(2) |
| | 186.46 | 193.20 | 200.32 | 207.85 | 215.81 | 224.24 | 233.18 | 242.68 | 252.80 | 263.59 | 275.04 |
| 33 | 1.069(4) | 6.038(3) | 1.162(3) | 5.593(3) | 4.017(1) | 4.349(3) | 6.835(1) | 3.205(3) | 2.669(2) | 2.331(3) | 4.265(2) |
| | 186.35 | 193.09 | 200.20 | 207.71 | 215.66 | 224.09 | 233.01 | 242.50 | 252.61 | 263.38 | 274.81 |

TABLE 2b. Transition Probabilities (s^{-1}) (Upper Entry) and Band Origins (nm) (Lower Entry) of the Second Negative Band System of $O_2^+(A; v' \rightarrow X; v'' = 11 - 21)$

| v' | v'' | | | | | | | | | | |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | |
| 0 | 1.578(5) | 9.855(4) | 5.397(4) | 2.463(4) | 9.084(3) | 2.693(3) | 5.916(2) | 1.048(2) | 1.488(1) | 1.303(0) | 3.903(-2) |
| | 470.40 | 506.49 | 547.59 | 594.15 | 648.20 | 710.50 | 783.98 | 870.78 | 976.00 | 1104.22 | 1266.05 |
| 1 | 2.518(4) | 8.078(4) | 1.168(5) | 1.081(5) | 7.217(4) | 3.700(4) | 1.400(4) | 4.005(3) | 8.197(2) | 1.266(2) | 1.407(1) |
| | 451.89 | 485.09 | 522.66 | 564.92 | 613.56 | 669.10 | 733.87 | 809.39 | 899.53 | 1007.35 | 1140.31 |
| 2 | 9.454(4) | 3.858(4) | 3.956(2) | 2.384(4) | 7.269(4) | 9.214(4) | 6.991(4) | 3.650(4) | 1.311(4) | 3.371(3) | 6.018(2) |
| | 435.29 | 466.01 | 500.58 | 539.21 | 583.36 | 633.34 | 691.08 | 757.65 | 836.07 | 928.43 | 1040.23 |
| 3 | 4.607(3) | 1.990(4) | 6.693(4) | 5.296(4) | 6.899(3) | 9.905(3) | 5.556(4) | 8.001(4) | 6.087(4) | 2.929(4) | 9.273(3) |
| | 420.35 | 448.93 | 480.93 | 516.47 | 556.83 | 602.20 | 654.16 | 713.50 | 782.64 | 863.00 | 958.78 |
| 4 | 3.763(4) | 6.720(4) | 2.180(4) | 3.130(3) | 4.425(4) | 4.794(4) | 7.118(3) | 1.004(4) | 5.505(4) | 7.238(4) | 4.867(4) |
| | 406.85 | 433.56 | 463.33 | 496.24 | 533.38 | 574.87 | 622.03 | 675.45 | 737.10 | 807.95 | 891.31 |
| 5 | 6.715(4) | 1.342(4) | 1.114(4) | 5.104(4) | 2.442(4) | 1.258(3) | 3.709(4) | 3.811(4) | 2.336(3) | 1.848(4) | 6.197(4) |
| | 394.61 | 419.69 | 447.53 | 478.15 | 512.54 | 550.73 | 593.87 | 642.38 | 697.88 | 761.08 | 834.60 |
| 6 | 1.881(4) | 1.001(4) | 5.162(4) | 1.882(4) | 5.380(3) | 4.092(4) | 1.782(4) | 3.410(3) | 3.787(4) | 2.459(4) | 2.779(2) |
| | 383.48 | 407.13 | 433.27 | 461.91 | 493.93 | 529.30 | 569.03 | 613.41 | 663.82 | 720.74 | 786.35 |
| 7 | 2.549(3) | 4.893(4) | 2.489(4) | 3.617(3) | 3.973(4) | 1.447(4) | 6.993(3) | 3.563(4) | 7.569(3) | 1.131(4) | 3.738(4) |
| | 373.34 | 395.72 | 420.37 | 447.28 | 477.24 | 510.17 | 546.98 | 587.87 | 634.01 | 685.74 | 744.87 |
| 8 | 3.618(4) | 3.974(4) | 5.682(1) | 3.549(4) | 2.024(4) | 4.075(3) | 3.335(4) | 6.064(3) | 1.395(4) | 2.793(4) | 2.287(2) |
| | 364.08 | 385.33 | 406.67 | 434.05 | 462.21 | 493.04 | 527.34 | 565.23 | 607.76 | 655.14 | 708.90 |
| 9 | 5.290(4) | 6.388(3) | 2.229(4) | 3.276(4) | 9.478(1) | 3.018(4) | 1.122(4) | 8.977(3) | 2.634(4) | 1.487(2) | 2.351(4) |
| | 355.62 | 375.86 | 398.03 | 422.08 | 448.65 | 477.64 | 509.76 | 545.09 | 584.54 | 628.23 | 677.50 |
| 10 | 3.143(4) | 3.631(3) | 4.055(4) | 5.647(3) | 1.888(4) | 2.295(4) | 1.675(3) | 2.702(4) | 2.411(3) | 1.732(4) | 1.388(4) |

| | | | | | | | | | | | | |
|----|----------|--------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 11 | 5.363(3) | 347.89 | 367.24 | 388.37 | 411.23 | 436.41 | 463.80 | 494.02 | 527.13 | 563.93 | 604.49 | 649.98 |
| | 340.86 | 345.99 | 352.36 | 371.78 | 392.67 | 415.57 | 440.33 | 467.48 | 497.02 | 529.61 | 565.23 | 604.80 |
| 12 | 1.346(3) | 334.51 | 352.36 | 371.78 | 392.67 | 415.57 | 440.33 | 467.48 | 497.02 | 529.61 | 565.23 | 604.80 |
| | 328.76 | 345.99 | 352.36 | 371.78 | 392.67 | 415.57 | 440.33 | 467.48 | 497.02 | 529.61 | 565.23 | 604.80 |
| 13 | 1.505(4) | 328.76 | 345.99 | 352.36 | 371.78 | 415.57 | 440.33 | 467.48 | 497.02 | 529.61 | 565.23 | 604.80 |
| | 328.76 | 345.99 | 352.36 | 371.78 | 392.67 | 415.57 | 440.33 | 467.48 | 497.02 | 529.61 | 565.23 | 604.80 |
| 14 | 2.965(4) | 323.57 | 340.24 | 1.077(4) | 377.68 | 398.82 | 421.56 | 446.39 | 473.25 | 502.70 | 534.68 | 569.95 |
| | 323.57 | 340.24 | 358.31 | 377.68 | 398.82 | 421.56 | 446.39 | 473.25 | 502.70 | 534.68 | 569.95 | 604.80 |
| 15 | 3.474(4) | 318.88 | 2.734(3) | 2.221(4) | 1.009(4) | 1.064(4) | 1.483(4) | 4.036(3) | 1.582(4) | 1.290(3) | 1.502(4) | 3.647(2) |
| | 318.88 | 335.07 | 352.58 | 371.31 | 391.72 | 413.64 | 437.51 | 463.29 | 491.48 | 522.00 | 555.57 | 604.80 |
| 16 | 2.994(4) | 314.66 | 2.036(2) | 2.624(4) | 1.427(3) | 1.873(4) | 4.702(3) | 1.226(4) | 6.729(3) | 8.319(3) | 7.281(3) | 6.382(3) |
| | 314.66 | 330.41 | 347.42 | 365.60 | 385.37 | 406.57 | 429.61 | 454.43 | 481.52 | 510.78 | 542.88 | 586.26 |
| 17 | 2.031(4) | 310.86 | 4.657(3) | 2.258(4) | 4.246(2) | 2.012(4) | 1.246(2) | 1.627(4) | 7.339(2) | 1.323(4) | 9.994(2) | 1.144(4) |
| | 310.86 | 326.22 | 342.80 | 360.48 | 379.69 | 400.25 | 422.56 | 446.55 | 472.68 | 500.85 | 531.68 | 586.26 |
| 18 | 1.079(4) | 307.46 | 1.124(4) | 1.519(4) | 4.424(3) | 1.591(4) | 1.465(3) | 1.443(4) | 5.502(2) | 1.249(4) | 3.853(2) | 1.079(4) |
| | 307.46 | 322.48 | 338.66 | 355.91 | 374.62 | 394.62 | 416.29 | 439.55 | 464.85 | 492.07 | 521.79 | 586.26 |
| 19 | 4.102(3) | 304.41 | 1.638(4) | 7.961(3) | 9.473(3) | 9.733(3) | 5.500(3) | 9.506(3) | 3.785(3) | 8.254(3) | 3.381(3) | 6.624(3) |
| | 304.41 | 319.12 | 334.96 | 351.83 | 370.11 | 389.61 | 410.72 | 433.35 | 457.92 | 484.31 | 513.07 | 586.26 |
| 20 | 7.539(2) | 301.69 | 1.871(4) | 2.970(3) | 1.301(4) | 4.481(3) | 9.176(3) | 4.641(3) | 7.229(3) | 3.824(3) | 6.573(3) | 2.551(3) |
| | 301.69 | 316.14 | 331.68 | 348.21 | 366.10 | 385.17 | 405.79 | 427.87 | 451.80 | 477.46 | 505.40 | 586.26 |
| 21 | 1.227(1) | 299.28 | 1.842(4) | 5.276(2) | 1.426(4) | 1.308(3) | 1.105(4) | 1.460(3) | 9.125(3) | 1.014(3) | 8.114(3) | 3.761(2) |
| | 299.28 | 313.49 | 328.77 | 345.00 | 362.55 | 381.25 | 401.44 | 423.03 | 446.41 | 471.45 | 498.67 | 586.26 |
| 22 | 7.825(2) | 297.15 | 1.640(4) | 1.141(1) | 1.359(4) | 8.732(1) | 1.108(4) | 1.325(2) | 9.235(3) | 2.724(1) | 7.870(3) | 5.233(1) |
| | 297.15 | 311.16 | 326.20 | 342.17 | 359.43 | 377.80 | 394.28 | 415.09 | 437.58 | 461.61 | 487.67 | 586.26 |
| 23 | 2.120(3) | 295.29 | 1.359(4) | 5.700(2) | 1.176(4) | 1.488(2) | 9.839(3) | 1.029(2) | 8.119(3) | 2.565(2) | 6.527(3) | 7.528(2) |
| | 295.29 | 309.11 | 323.95 | 339.70 | 356.70 | 374.79 | 394.28 | 415.09 | 437.58 | 461.61 | 487.67 | 586.26 |
| 24 | 3.403(3) | 293.66 | 1.066(4) | 1.498(3) | 9.512(3) | 7.977(2) | 8.036(3) | 6.918(2) | 6.471(3) | 9.868(2) | 4.838(3) | 1.689(3) |
| | 293.66 | 307.33 | 321.99 | 337.55 | 354.33 | 372.17 | 391.39 | 411.88 | 434.02 | 457.65 | 483.25 | 586.26 |
| 25 | 4.321(3) | 292.25 | 8.045(3) | 2.353(3) | 7.316(3) | 1.539(3) | 6.176(3) | 1.393(3) | 4.801(3) | 1.718(3) | 3.290(3) | 2.408(3) |
| | 292.25 | 305.79 | 320.31 | 335.69 | 352.29 | 369.92 | 388.90 | 409.13 | 430.96 | 454.25 | 479.46 | 586.26 |
| 26 | 4.783(3) | 291.05 | 5.891(3) | 2.927(3) | 5.423(3) | 2.106(3) | 4.540(3) | 1.932(3) | 3.379(3) | 2.212(3) | 2.088(3) | 2.761(3) |
| | 291.05 | 304.48 | 318.86 | 334.11 | 350.55 | 368.00 | 386.78 | 406.78 | 428.35 | 451.35 | 476.24 | 586.26 |
| 27 | 4.826(3) | 290.04 | 4.222(3) | 3.174(3) | 3.915(3) | 2.407(3) | 3.233(3) | 2.215(3) | 2.287(3) | 2.414(3) | 1.252(3) | 2.782(3) |
| | 290.04 | 303.37 | 317.65 | 332.78 | 349.08 | 366.38 | 384.99 | 404.80 | 426.16 | 448.93 | 473.53 | 586.26 |
| 28 | 4.546(3) | 289.20 | 2.982(3) | 3.134(3) | 2.774(3) | 2.453(3) | 2.251(3) | 2.255(3) | 1.506(3) | 2.369(3) | 7.165(2) | 2.571(3) |
| | 289.20 | 302.45 | 316.64 | 331.67 | 347.86 | 365.04 | 383.51 | 403.17 | 424.35 | 446.91 | 471.29 | 586.26 |
| 29 | 4.054(3) | 288.51 | 2.085(3) | 2.886(3) | 1.941(3) | 2.305(3) | 1.545(3) | 2.112(3) | 9.741(2) | 2.157(3) | 3.954(2) | 2.232(3) |
| | 288.51 | 301.69 | 315.81 | 330.76 | 346.86 | 363.94 | 382.30 | 401.83 | 422.86 | 445.27 | 469.46 | 586.26 |
| 30 | 3.453(3) | 287.96 | 1.449(3) | 2.513(3) | 1.348(3) | 2.033(3) | 1.052(3) | 1.856(3) | 6.249(2) | 1.853(3) | 2.127(2) | 1.848(3) |
| | 287.96 | 301.09 | 315.15 | 330.04 | 346.06 | 363.06 | 381.33 | 400.76 | 421.68 | 443.95 | 468.00 | 586.26 |

TABLE 2b. (continued)

| v' | v'' | | | | | | | | | | | | | | |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|--|--|--|--|
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | | | | |
| 31 | 2.825(3) | 1.004(3) | 2.089(3) | 9.324(2) | 1.704(3) | 7.138(2) | 1.549(3) | 4.003(2) | 1.521(3) | 1.128(2) | 1.472(3) | | | | |
| | 287.52 | 300.61 | 314.63 | 329.46 | 345.44 | 362.37 | 380.56 | 399.91 | 420.74 | 442.91 | 466.85 | | | | |
| 32 | 2.231(3) | 6.935(2) | 1.668(3) | 6.432(2) | 1.368(3) | 4.839(2) | 1.240(3) | 2.575(2) | 1.201(3) | 5.981(1) | 1.136(3) | | | | |
| | 287.19 | 300.24 | 314.23 | 329.02 | 344.95 | 361.84 | 379.97 | 399.26 | 420.02 | 442.12 | 465.97 | | | | |
| 33 | 1.707(3) | 4.781(2) | 1.286(3) | 4.426(2) | 1.059(3) | 3.281(2) | 9.569(2) | 1.668(2) | 9.171(2) | 3.209(1) | 8.527(2) | | | | |
| | 286.93 | 299.97 | 313.92 | 328.69 | 344.59 | 361.44 | 379.53 | 398.77 | 419.48 | 441.52 | 465.30 | | | | |

TABLE 2c. Transition Probabilities (s^{-1}) (Upper Entry) and Band Origins (nm) (Lower Entry) of the Second Negative Band System of $O_2^+(A; v' \rightarrow X; v'' = 22 - 32)$

| v' | v'' | | | | | | | | | | | | | | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|------------|------------|------------|--|--|--|--|
| | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | | | | |
| 0 | 8.752(-3) | 1.238(-3) | 9.630(-4) | 5.098(-5) | 5.827(-5) | 3.616(-5) | 1.132(-6) | 1.414(-11) | -1.749(-6) | -1.268(-5) | -7.481(-6) | | | | |
| | 1473.53 | 1751.05 | 2140.65 | 2721.98 | 3690.37 | 5615.77 | 11244.16 | 318425.22 | -12580.88 | -6299.33 | -4261.07 | | | | |
| 1 | 8.919(-1) | 3.207(-2) | 3.711(-3) | 1.592(-5) | 4.886(-5) | 5.946(-5) | 6.406(-6) | 5.099(-8) | 7.058(-10) | -7.327(-7) | -1.996(-6) | | | | |
| | 1305.93 | 1519.34 | 1804.27 | 2200.34 | 2792.75 | 3771.24 | 5680.86 | 11082.14 | 131421.33 | -13956.31 | -6775.61 | | | | |
| 2 | 7.335(1) | 5.811(0) | 2.762(-1) | 7.898(-3) | 7.929(-5) | 7.241(-7) | 1.350(-7) | 9.518(-8) | 5.563(-9) | 8.965(-13) | -2.468(-9) | | | | |
| | 1176.31 | 1346.69 | 1565.88 | 1855.79 | 2260.15 | 2860.87 | 3840.11 | 5726.91 | 10870.97 | 78574.06 | -15820.48 | | | | |
| 3 | 1.977(3) | 2.807(2) | 2.431(1) | 1.336(0) | 4.425(-2) | 1.045(-4) | 4.256(-5) | 1.655(-6) | 5.861(-6) | 1.108(-6) | 2.404(-9) | | | | |
| | 1073.22 | 1213.26 | 1388.34 | 1611.56 | 1907.99 | 2319.08 | 2923.37 | 3902.03 | 5758.69 | 10594.41 | 54190.63 | | | | |
| 4 | 1.959(4) | 5.068(3) | 8.254(2) | 8.303(1) | 4.869(0) | 1.745(-1) | 1.580(-3) | 2.551(-6) | 2.655(-5) | 8.595(-6) | 4.229(-7) | | | | |
| | 989.39 | 1107.21 | 1251.20 | 1429.67 | 1658.21 | 1960.19 | 2375.19 | 2983.08 | 3958.86 | 5769.13 | 10266.90 | | | | |
| 5 | 6.331(4) | 3.400(4) | 1.062(4) | 2.043(3) | 2.353(2) | 1.531(1) | 5.531(-1) | 8.991(-3) | 2.123(-5) | 7.170(-6) | 3.070(-7) | | | | |
| | 920.00 | 1021.03 | 1142.25 | 1289.16 | 1472.12 | 1705.36 | 2011.05 | 2430.39 | 3041.07 | 4006.89 | 5759.25 | | | | |
| 6 | 3.546(4) | 6.693(4) | 4.907(4) | 1.931(4) | 4.392(3) | 5.732(2) | 4.252(1) | 1.668(0) | 2.830(-2) | 3.656(-4) | 1.317(-6) | | | | |
| | 861.71 | 949.73 | 1053.75 | 1177.55 | 1328.34 | 1515.35 | 1752.00 | 2061.93 | 2485.36 | 3095.07 | 4045.98 | | | | |
| 7 | 8.371(3) | 1.035(4) | 5.585(4) | 6.121(4) | 3.090(4) | 8.350(3) | 1.265(3) | 1.058(2) | 4.651(0) | 9.202(-2) | 1.734(-3) | | | | |
| | 812.15 | 889.88 | 980.57 | 1086.90 | 1214.12 | 1368.49 | 1558.60 | 1799.19 | 2113.37 | 2538.60 | 3144.84 | | | | |
| 8 | 2.488(4) | 2.624(4) | 3.194(1) | 3.526(4) | 6.629(4) | 4.397(4) | 1.448(4) | 2.566(3) | 2.429(2) | 1.231(1) | 3.428(-1) | | | | |
| | 769.57 | 839.02 | 919.18 | 1011.98 | 1121.38 | 1251.80 | 1409.01 | 1602.76 | 1847.41 | 2164.33 | 2590.00 | | | | |
| 9 | 1.337(4) | 5.486(3) | 3.287(4) | 6.724(3) | 1.434(4) | 6.129(4) | 5.675(4) | 2.325(4) | 4.848(3) | 5.384(2) | 3.329(1) | | | | |
| | 732.70 | 795.38 | 867.07 | 949.17 | 1044.78 | 1157.09 | 1290.15 | 1450.73 | 1648.31 | 1896.02 | 2214.91 | | | | |
| 10 | 4.558(3) | 2.502(4) | 6.325(2) | 2.283(4) | 2.110(4) | 1.581(3) | 4.697(4) | 6.651(4) | 3.478(4) | 8.807(3) | 1.195(3) | | | | |
| | 700.62 | 757.72 | 822.50 | 896.02 | 980.74 | 1079.06 | 1193.89 | 1330.13 | 1494.37 | 1695.16 | 1945.60 | | | | |
| 11 | 2.165(4) | 1.562(3) | 1.766(4) | 1.149(4) | 6.835(3) | 3.000(4) | 1.876(3) | 2.684(4) | 6.897(4) | 4.853(4) | 1.553(4) | | | | |
| | 672.71 | 725.18 | 784.29 | 850.87 | 926.90 | 1014.24 | 1115.05 | 1233.00 | 1372.86 | 1540.49 | 1744.57 | | | | |
| 12 | 7.218(3) | 9.100(3) | 1.364(4) | 3.205(3) | 2.129(4) | 2.154(1) | 2.574(4) | 1.371(4) | 7.900(3) | 5.981(4) | 6.157(4) | | | | |
| | 648.41 | 697.02 | 751.46 | 812.36 | 881.39 | 960.00 | 1049.84 | 1153.76 | 1275.33 | 1418.75 | 1590.05 | | | | |

| | | | | | | | | | | | |
|----|--------------------|--------------------|---------------------|--------------------|---------------------|--------------------|--------------------|---------------------|---------------------|----------------------|---------------------|
| 13 | 7.385(2) 627.16 | 1.714(4) 672.52 | 2.558(0) 723.06 | 1.745(4) 779.28 | -1.295(3) 842.58 | 1.687(4) 914.14 | 7.340(3) 995.23 | 1.169(4) 1088.14 | 2.738(4) 1195.64 | 6.729(-1) 1320.81 | 3.936(4) 1468.05 |
| 14 | 1.088(4) 608.53 | 5.741(3) 651.15 | 8.692(3) 698.41 | 7.802(3) 750.72 | 6.820(3) 809.29 | 1.122(4) 875.09 | 4.411(3) 949.12 | 1.828(4) 1033.26 | 7.122(2) 1129.71 | 2.997(4) 1240.81 | 7.996(3) 1369.89 |
| 15 | 1.401(4) 592.16 | 8.719(1) 632.44 | 1.360(4) 676.94 | 1.106(1) 725.97 | 1.402(4) 780.60 | 1.196(1) 841.64 | 1.541(4) 909.90 | 3.749(2) 986.95 | 1.843(4) 1074.57 | 3.852(3) 1174.62 | 1.759(4) 1289.65 |
| 16 | 7.010(3) 577.77 | 5.659(3) 616.05 | 6.536(3) 658.19 | 5.713(3) 704.45 | 6.291(3) 755.78 | 6.319(3) 812.85 | 6.575(3) 876.35 | 7.023(3) 947.59 | 8.662(3) 1028.09 | 7.053(3) 1119.30 | 1.629(4) 1223.27 |
| 17 | 8.163(2) 565.09 | 1.062(4) 601.66 | 4.414(2) 641.79 | 1.048(4) 685.70 | 1.351(2) 734.23 | 1.096(4) 787.99 | 3.201(0) 847.51 | 1.210(4) 913.97 | 2.781(1) 988.63 | 1.499(4) 1072.68 | 5.472(0) 1167.80 |
| 18 | 5.767(2) 553.93 | 9.366(3) 589.03 | 1.154(3) 627.44 | 8.008(3) 669.34 | 2.185(3) 715.51 | 6.731(3) 766.46 | 3.733(3) 822.66 | 5.663(3) 885.13 | 5.873(3) 954.98 | 5.289(3) 1033.18 | 8.273(3) 1121.14 |
| 19 | 3.820(3) 544.12 | 4.851(3) 577.94 | 4.888(3) 614.88 | 3.020(3) 655.06 | 6.304(3) 699.22 | 1.401(3) 747.79 | 7.825(3) 801.20 | 3.455(2) 860.34 | 9.419(3) 926.17 | 5.344(-1) 999.55 | 1.159(4) 1081.65 |
| 20 | 6.708(3) 535.50 | 1.230(3) 568.23 | 7.191(3) 603.89 | 2.410(2) 642.61 | 7.483(3) 685.05 | 5.435(1) 731.61 | 7.172(3) 782.65 | 9.651(2) 838.98 | 6.229(3) 901.47 | 3.087(3) 970.84 | 5.232(3) 1048.11 |
| 21 | 7.542(3) 527.95 | 5.538(0) 559.73 | 6.906(3) 594.31 | 3.367(2) 631.77 | 5.747(3) 672.74 | 1.674(3) 717.59 | 3.929(3) 766.63 | 3.807(3) 820.60 | 1.901(3) 880.28 | 6.380(3) 946.31 | 4.545(2) 1019.58 |
| 22 | 6.596(3) 521.36 | 5.630(2) 552.33 | 5.061(3) 585.97 | 1.792(3) 622.35 | 3.147(3) 662.08 | 3.631(3) 705.47 | 1.193(3) 752.81 | 5.355(3) 804.79 | 5.563(1) 862.12 | 6.268(3) 925.35 | 4.905(2) 995.28 |
| 23 | 4.844(3) 515.64 | 1.743(3) 545.91 | 2.975(3) 578.75 | 3.159(3) 614.22 | 1.170(3) 652.88 | 4.529(3) 695.04 | 6.687(1) 740.94 | 4.996(3) 791.24 | 4.425(2) 846.58 | 4.101(3) 907.47 | 2.466(3) 974.64 |
| 24 | 3.097(3) 510.70 | 2.737(3) 540.38 | 1.395(3) 572.54 | 3.815(3) 607.22 | 2.048(2) 644.98 | 4.315(3) 686.09 | 1.587(2) 730.78 | 3.634(3) 779.66 | 1.562(3) 833.35 | 1.905(3) 892.28 | 3.832(3) 957.13 |
| 25 | 1.747(3) 506.46 | 3.239(3) 535.64 | 4.802(2) 567.22 | 3.778(3) 601.25 | 2.682(0) 638.24 | 3.488(3) 678.47 | 7.224(2) 722.14 | 2.193(3) 769.84 | 2.404(3) 822.13 | 5.697(2) 879.44 | 3.983(3) 942.38 |
| 26 | 8.677(2) 502.87 | 3.275(3) 531.63 | 8.720(1) 562.72 | 3.312(3) 596.19 | 1.740(2) 632.55 | 2.523(3) 672.04 | 1.247(3) 714.86 | 1.120(3) 761.57 | 2.687(3) 812.71 | 5.697(1) 868.67 | 3.347(3) 930.01 |
| 27 | 3.709(2) 499.86 | 2.995(3) 528.26 | 1.585(-2) 558.95 | 2.679(3) 591.96 | 4.289(2) 627.78 | 1.687(3) 666.67 | 1.534(3) 708.79 | 4.782(2) 754.68 | 2.530(3) 804.87 | 1.988(1) 859.71 | 2.467(3) 919.75 |
| 28 | 1.286(2) 497.36 | 2.559(3) 525.47 | 4.484(1) 555.83 | 2.053(3) 588.46 | 6.206(2) 623.85 | 1.067(3) 662.24 | 1.581(3) 703.78 | 1.604(2) 749.00 | 2.146(3) 798.41 | 1.537(2) 852.35 | 1.670(3) 911.34 |
| 29 | 3.060(1) 495.33 | 2.083(3) 523.20 | 1.170(2) 553.29 | 1.517(3) 585.61 | 7.064(2) 620.65 | 6.491(2) 658.63 | 1.459(3) 699.71 | 3.468(1) 744.40 | 1.701(3) 793.18 | 2.887(2) 846.40 | 1.071(3) 904.53 |
| 30 | 2.342(0) 493.70 | 1.635(3) 521.38 | 1.690(2) 551.26 | 1.094(3) 583.34 | 6.986(2) 618.10 | 3.862(2) 655.75 | 1.251(3) 696.46 | 1.544(0) 740.72 | 1.290(3) 789.01 | 3.631(2) 841.65 | 6.645(2) 899.11 |
| 31 | 1.057(0) 492.42 | 1.247(3) 519.96 | 1.890(2) 549.66 | 7.764(2) 581.55 | 6.287(2) 616.09 | 2.277(2) 653.50 | 1.017(3) 693.92 | 2.859(0) 737.85 | 9.499(2) 785.75 | 3.743(2) 837.94 | 4.064(2) 894.88 |
| 32 | 6.248(0) 491.43 | 9.297(2) 518.86 | 1.821(2) 548.44 | 5.451(2) 580.18 | 5.283(2) 614.55 | 1.347(2) 651.77 | 7.931(2) 691.97 | 1.116(1) 735.64 | 6.849(2) 783.25 | 3.418(2) 835.09 | 2.481(2) 891.63 |
| 33 | 1.025(1) 490.69 | 6.795(2) 518.03 | 1.590(2) 547.51 | 3.796(2) 579.15 | 4.210(2) 613.39 | 8.058(1) 650.46 | 5.987(2) 690.50 | 1.673(1) 733.98 | 4.864(2) 781.36 | 2.872(2) 832.95 | 1.527(2) 889.19 |

TABLE 2d. Transition Probabilities (s^{-1}) (Upper Entry) and Band Origins (nm) (Lower Entry) of the Second Negative Band System of $O_2^+(A; v' \rightarrow X; v'' = 33 - 43)$

| v' | v'' | | | | | | | | | | | |
|------|------------|------------|------------|------------|------------|-------------|------------|------------|------------|------------|-------------|--|
| | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | |
| 0 | -6.373(-6) | -9.087(-5) | -1.948(-4) | -1.629(-4) | -3.337(-5) | -2.065(-5) | -2.154(-4) | -4.667(-4) | -5.583(-4) | -4.224(-4) | -1.802(-4) | |
| | -3251.42 | -2649.11 | -2250.17 | -1967.22 | -1756.32 | -1593.18 | -1463.45 | -1358.13 | -1271.17 | -1198.36 | -1136.64 | |
| 1 | -2.145(-7) | -1.952(-5) | -6.500(-5) | -7.752(-5) | -3.030(-5) | -9.555(-7) | -7.139(-5) | -2.105(-4) | -3.029(-4) | -2.700(-4) | -1.434(-4) | |
| | -4535.91 | -3443.63 | -2798.63 | -2373.96 | -2073.50 | -1849.86 | -1677.23 | -1540.33 | -1429.43 | -1338.01 | -1261.53 | |
| 2 | -2.782(-8) | -2.631(-8) | -2.382(-9) | -1.247(-7) | -3.210(-7) | -3.275(-7) | -1.354(-7) | -1.483(-9) | -9.217(-8) | -3.220(-7) | -4.983(-7) | |
| | -7348.41 | -4854.08 | -3663.84 | -2968.61 | -2513.21 | -2192.01 | -1953.73 | -1770.43 | -1625.48 | -1508.30 | -1411.81 | |
| 3 | -4.061(-9) | -1.162(-6) | -7.058(-6) | -1.132(-5) | -4.723(-6) | -7.027(-7) | -2.157(-5) | -6.240(-5) | -9.050(-5) | -8.046(-5) | -4.089(-5) | |
| | -18375.19 | -8041.85 | -5228.06 | -3918.56 | -3162.21 | -2669.95 | -2324.61 | -2069.66 | -1874.28 | -1720.18 | -1595.79 | |
| 4 | 4.175(-10) | -6.128(-8) | -1.575(-6) | -4.369(-6) | -2.680(-6) | -1.898(-7) | -1.218(-5) | -4.061(-5) | -6.405(-5) | -6.066(-5) | -3.291(-5) | |
| | 40773.41 | -22025.20 | -8902.46 | -5673.80 | -4214.29 | -3383.04 | -2847.12 | -2473.87 | -2199.78 | -1990.49 | -1825.81 | |
| 5 | 7.496(-10) | 2.876(-9) | -6.922(-9) | -7.008(-8) | -3.990(-8) | -1.945(-8) | -4.323(-7) | -1.505(-6) | -2.742(-6) | -3.076(-6) | -2.053(-6) | |
| | 9924.65 | 32434.99 | -27704.63 | -9998.49 | -6209.08 | -4558.75 | -3636.38 | -3048.86 | -2643.00 | -2346.56 | -2121.03 | |
| 6 | 5.756(-8) | 2.818(-7) | 2.154(-8) | -2.994(-8) | -1.277(-8) | -1.345(-8) | -4.982(-7) | -2.494(-6) | -5.542(-6) | -6.679(-6) | -4.250(-6) | |
| | 5737.75 | 9582.59 | 26716.59 | -37749.84 | -11424.73 | -6857.14 | -4963.42 | -3929.79 | -3280.49 | -2835.83 | -2512.92 | |
| 7 | 7.573(-5) | 1.328(-6) | 6.757(-7) | 8.838(-8) | -1.375(-9) | -1.716(-8) | -9.948(-7) | -3.851(-6) | -6.735(-6) | -7.596(-6) | -5.266(-6) | |
| | 4079.86 | 5708.47 | 9237.67 | 22556.91 | -59855.28 | -13331.38 | -7653.94 | -5445.31 | -4273.31 | -3548.51 | -3056.97 | |
| 8 | 8.681(-3) | 3.413(-4) | 1.339(-5) | 5.485(-9) | 1.093(-9) | -1.180(-11) | -5.945(-9) | -7.322(-7) | -3.377(-6) | -3.933(-6) | -1.312(-6) | |
| | 3192.59 | 4110.20 | 5669.86 | 8892.76 | 19450.83 | -145088.95 | -15991.56 | -8656.09 | -6028.03 | -4679.68 | -3860.97 | |
| 9 | 1.291(0) | 3.820(-2) | 3.625(-4) | 3.743(-5) | 3.678(-7) | 3.044(-7) | 1.200(-11) | -6.273(-9) | -1.564(-7) | -2.433(-9) | -1.180(-6) | |
| | 2641.23 | 3239.57 | 4136.39 | 5623.14 | 8561.84 | 17095.96 | 350548.81 | -19944.17 | -9949.65 | -6742.91 | -5164.85 | |
| 10 | 9.282(1) | 4.510(0) | 1.298(-1) | 4.294(-4) | 2.694(-6) | 1.441(-5) | 6.386(-8) | 1.908(-9) | -2.565(-8) | -5.704(-8) | -1.423(-6) | |
| | 2267.03 | 2694.13 | 3286.76 | 4160.93 | 5577.51 | 8265.31 | 15302.95 | 80943.88 | -26307.57 | -11653.68 | -7626.46 | |
| 11 | 2.622(3) | 2.535(2) | 1.461(1) | 4.476(-1) | 4.003(-3) | 9.455(-5) | 1.473(-5) | 2.316(-6) | 6.957(-9) | -4.037(-9) | -1.839(-7) | |
| | 1998.67 | 2323.40 | 2751.20 | 3338.25 | 4192.55 | 5548.94 | 8027.37 | 13970.16 | 47136.37 | -37618.19 | -13909.08 | |
| 12 | 2.568(4) | 5.445(3) | 6.518(2) | 4.554(1) | 1.698(0) | 2.903(-2) | 5.581(-4) | 1.057(-5) | 2.776(-6) | 6.639(-8) | -1.336(-10) | |
| | 1798.44 | 2057.16 | 2385.60 | 2814.83 | 3398.79 | 4238.75 | 5547.00 | 7856.38 | 13000.68 | 34339.36 | -61760.88 | |
| 13 | 6.835(4) | 3.869(4) | 1.052(4) | 1.581(3) | 1.363(2) | 6.348(0) | 1.587(-1) | 3.020(-3) | 9.835(-6) | 1.117(-6) | 1.705(-7) | |
| | 1643.93 | 1857.46 | 2121.14 | 2453.84 | 2886.12 | 3470.04 | 4300.32 | 5569.54 | 7741.02 | 12287.42 | 27722.72 | |
| 14 | 1.541(4) | 6.318(4) | 5.202(4) | 1.870(4) | 3.581(3) | 3.852(2) | 2.280(1) | 7.557(-1) | 1.544(-2) | 6.718(-5) | 1.191(-9) | |
| | 1521.81 | 1703.04 | 1922.12 | 2191.36 | 2529.73 | 2967.40 | 3554.24 | 4379.02 | 5618.12 | 7680.64 | 11780.65 | |
| 15 | 2.418(4) | 8.478(2) | 4.413(4) | 6.014(4) | 2.985(4) | 7.418(3) | 1.010(3) | 7.641(1) | 3.287(0) | 7.990(-2) | 5.849(-4) | |
| | 1423.43 | 1580.77 | 1767.80 | 1993.00 | 2269.03 | 2614.98 | 3060.24 | 3652.59 | 4476.02 | 5694.29 | 7674.47 | |
| 16 | 2.616(3) | 3.154(4) | 4.765(3) | 1.857(4) | 5.672(4) | 4.162(4) | 1.382(4) | 2.428(3) | 2.369(2) | 1.313(1) | 3.971(-1) | |
| | 1342.99 | 1482.19 | 1645.41 | 1838.81 | 2071.28 | 2355.78 | 2711.15 | 3166.01 | 3766.64 | 4593.67 | 5801.20 | |

| | | | | | | | | | | | |
|----|----------|-----------|----------|-----------|----------|----------|----------|----------|----------|----------|----------|
| 17 | 2.021(4) | 2.182(3) | 2.055(4) | 2.097(4) | 1.463(3) | 3.929(4) | 4.867(4) | 2.264(4) | 5.267(3) | 6.702(2) | 4.800(1) |
| | 1276.43 | 1401.53 | 1546.60 | 1716.27 | 1917.11 | 2158.36 | 2452.94 | 2819.43 | 3286.06 | 3898.37 | 4734.74 |
| 18 | 7.360(3) | 8.993(3) | 1.520(4) | 3.489(3) | 2.942(4) | 3.957(3) | 1.543(4) | 4.481(4) | 3.164(4) | 1.009(4) | 1.699(3) |
| | 1220.89 | 1334.85 | 1465.80 | 1617.33 | 1794.49 | 2004.18 | 2255.72 | 2561.97 | 2941.54 | 3422.78 | 4051.08 |
| 19 | 1.427(2) | 1.536(4) | 1.200(1) | 2.027(4) | 2.041(3) | 1.819(4) | 1.882(4) | 7.307(2) | 2.867(4) | 3.600(4) | 1.662(4) |
| | 1174.21 | 1279.25 | 1399.02 | 1536.42 | 1695.42 | 1881.39 | 2101.37 | 2364.69 | 2684.41 | 3079.54 | 3578.96 |
| 20 | 5.978(3) | 5.175(3) | 8.590(3) | 7.534(3) | 8.098(3) | 1.502(4) | 2.057(3) | 2.433(4) | 4.721(3) | 8.877(3) | 3.070(4) |
| | 1134.79 | 1232.60 | 1343.42 | 1469.62 | 1614.44 | 1782.20 | 1978.38 | 2210.08 | 2486.91 | 2822.41 | 3236.30 |
| 21 | 9.016(3) | 2.861(0) | 1.182(4) | 4.202(1) | 1.509(4) | 7.742(1) | 1.737(4) | 3.336(3) | 1.170(4) | 1.682(4) | 2.252(0) |
| | 1101.41 | 1193.32 | 1296.90 | 1414.12 | 1547.72 | 1701.23 | 1879.11 | 2086.92 | 2332.04 | 2624.59 | 2978.86 |
| 22 | 6.282(3) | 2.494(3) | 5.941(3) | 5.005(3) | 6.451(3) | 6.236(3) | 9.102(3) | 4.283(3) | 1.452(4) | 1.936(2) | 1.663(4) |
| | 1073.12 | 1160.18 | 1257.85 | 1367.83 | 1492.43 | 1634.67 | 1798.23 | 1987.63 | 2208.75 | 2469.46 | 2780.60 |
| 23 | 2.444(3) | 5.505(3) | 9.644(2) | 8.520(3) | 3.034(2) | 1.100(4) | 2.713(2) | 1.246(4) | 1.274(3) | 1.106(4) | 5.827(3) |
| | 1049.15 | 1132.22 | 1225.05 | 1329.13 | 1446.48 | 1579.70 | 1731.93 | 1906.95 | 2109.56 | 2346.13 | 2625.21 |
| 24 | 3.614(2) | 5.890(3) | 8.056(1) | 6.980(3) | 1.065(3) | 7.527(3) | 2.168(3) | 8.371(3) | 2.042(3) | 1.012(4) | 5.060(2) |
| | 1028.90 | 1108.67 | 1197.53 | 1296.79 | 1408.26 | 1534.23 | 1677.43 | 1841.08 | 2029.25 | 2247.22 | 2501.99 |
| 25 | 2.951(1) | 4.460(3) | 1.281(3) | 3.712(3) | 3.671(3) | 2.663(3) | 5.954(3) | 2.075(3) | 7.084(3) | 2.440(3) | 6.415(3) |
| | 1011.87 | 1088.92 | 1174.51 | 1269.84 | 1376.54 | 1496.66 | 1632.61 | 1787.24 | 1964.03 | 2167.51 | 2403.58 |
| 26 | 4.901(2) | 2.691(3) | 2.482(3) | 1.303(3) | 4.878(3) | 2.984(2) | 6.650(3) | 4.253(0) | 7.529(3) | 1.035(1) | 7.822(3) |
| | 997.63 | 1072.44 | 1155.37 | 1247.50 | 1350.32 | 1465.72 | 1595.86 | 1743.29 | 1911.09 | 2103.21 | 2324.77 |
| 27 | 1.015(3) | 1.353(3) | 2.953(3) | 2.247(2) | 4.526(3) | 7.463(1) | 5.089(3) | 7.870(2) | 4.934(3) | 1.482(3) | 4.791(3) |
| | 985.83 | 1058.83 | 1139.58 | 1229.11 | 1328.80 | 1440.40 | 1565.89 | 1707.59 | 1868.27 | 2051.47 | 2261.71 |
| 28 | 1.312(3) | 5.682(2) | 2.803(3) | 2.311(-1) | 3.473(3) | 6.250(2) | 3.118(3) | 1.967(3) | 2.339(3) | 3.067(3) | 1.802(3) |
| | 976.17 | 1047.69 | 1126.69 | 1214.13 | 1311.31 | 1419.86 | 1541.66 | 1678.81 | 1833.87 | 2010.07 | 2211.49 |
| 29 | 1.362(3) | 1.914(2) | 2.344(3) | 1.107(2) | 2.385(3) | 1.121(3) | 1.641(3) | 2.533(3) | 8.155(2) | 3.509(3) | 3.557(2) |
| | 968.36 | 1038.70 | 1116.30 | 1202.07 | 1297.26 | 1403.40 | 1522.27 | 1655.85 | 1806.51 | 1977.24 | 2171.82 |
| 30 | 1.247(3) | 4.480(1) | 1.816(3) | 2.620(2) | 1.535(3) | 1.325(3) | 7.691(2) | 2.492(3) | 1.825(2) | 3.117(3) | 3.763(0) |
| | 962.15 | 1031.56 | 1108.06 | 1192.52 | 1286.14 | 1390.40 | 1506.99 | 1637.78 | 1785.02 | 1951.53 | 2140.84 |
| 31 | 1.051(3) | 3.841(0) | 1.344(3) | 3.488(2) | 9.545(2) | 1.285(3) | 3.279(2) | 2.127(3) | 1.124(1) | 2.428(3) | 7.253(1) |
| | 957.31 | 1025.99 | 1101.63 | 1185.08 | 1277.49 | 1380.30 | 1495.13 | 1623.78 | 1768.41 | 1931.69 | 2116.99 |
| 32 | 8.382(2) | 8.666(-1) | 9.654(2) | 3.629(2) | 5.862(2) | 1.111(3) | 1.287(2) | 1.673(3) | 7.909(0) | 1.762(3) | 1.961(2) |
| | 953.59 | 1021.73 | 1096.72 | 1179.40 | 1270.89 | 1372.60 | 1486.09 | 1613.13 | 1755.78 | 1916.63 | 2098.91 |
| 33 | 6.408(2) | 6.287(0) | 6.808(2) | 3.283(2) | 3.606(2) | 8.917(2) | 4.671(1) | 1.251(3) | 3.713(1) | 1.229(3) | 2.600(2) |
| | 950.81 | 1018.53 | 1093.03 | 1175.14 | 1265.94 | 1366.83 | 1479.33 | 1605.17 | 1746.35 | 1905.40 | 2085.45 |

TABLE 2e. Transition Probabilities (s^{-1}) (Upper Entry) and Band Origins (nm) (Lower Entry) of the Second Negative Band System of $O_2^+(A; v' \rightarrow X; v'' = 44 - 54)$

| v' | v'' | | | | | | | | | | | | | | | |
|------|-------------|-------------|------------|-------------|------------|------------|------------|------------|------------|------------|------------|--|--|--|--|--|
| | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | | | | | |
| 0 | -1.602(-5) | -3.433(-5) | -2.144(-4) | -4.565(-4) | -6.538(-4) | -7.420(-4) | -7.110(-4) | -5.915(-4) | -4.310(-4) | -2.727(-4) | -1.449(-4) | | | | | |
| | -1083.78 | -1038.14 | -998.47 | -963.80 | -933.38 | -906.60 | -882.95 | -862.03 | -843.51 | -827.10 | -812.57 | | | | | |
| 1 | -2.690(-5) | -6.239(-6) | -9.527(-5) | -2.449(-4) | -3.852(-4) | -4.644(-4) | -4.651(-4) | -4.010(-4) | -3.013(-4) | -1.966(-4) | -1.083(-4) | | | | | |
| | -1196.75 | -1141.34 | -1093.57 | -1052.12 | -1015.98 | -984.32 | -956.51 | -932.01 | -910.39 | -891.30 | -874.45 | | | | | |
| 2 | -5.097(-7) | -3.789(-7) | -2.004(-7) | -6.155(-8) | -2.341(-9) | -1.680(-8) | -7.483(-8) | -1.436(-7) | -1.997(-7) | -2.323(-7) | -2.405(-7) | | | | | |
| | -1331.17 | -1262.97 | -1204.73 | -1154.62 | -1111.24 | -1073.48 | -1040.48 | -1011.56 | -986.14 | -963.78 | -944.11 | | | | | |
| 3 | -5.793(-6) | -4.658(-6) | -4.232(-5) | -1.008(-4) | -1.543(-4) | -1.834(-4) | -1.819(-4) | -1.551(-4) | -1.150(-4) | -7.338(-5) | -3.890(-5) | | | | | |
| | -1493.53 | -1408.20 | -1336.19 | -1274.83 | -1222.15 | -1176.63 | -1137.10 | -1102.64 | -1072.51 | -1046.12 | -1022.98 | | | | | |
| 4 | -5.467(-6) | -2.823(-6) | -3.134(-5) | -7.845(-5) | -1.236(-4) | -1.503(-4) | -1.519(-4) | -1.320(-4) | -9.981(-5) | -6.518(-5) | -3.566(-5) | | | | | |
| | -1693.17 | -1584.34 | -1493.76 | -1417.49 | -1352.65 | -1297.12 | -1249.25 | -1207.78 | -1171.72 | -1140.29 | -1112.86 | | | | | |
| 5 | -5.474(-7) | -3.303(-8) | -1.328(-6) | -4.043(-6) | -6.995(-6) | -9.014(-6) | -9.513(-6) | -8.581(-6) | -6.745(-6) | -4.634(-6) | -2.742(-6) | | | | | |
| | -1944.10 | -1801.99 | -1685.72 | -1589.22 | -1508.18 | -1439.46 | -1380.74 | -1330.26 | -1286.65 | -1248.85 | -1216.02 | | | | | |
| 6 | -7.795(-7) | -4.415(-7) | -5.088(-6) | -1.313(-5) | -2.107(-5) | -2.574(-5) | -2.574(-5) | -2.168(-5) | -1.545(-5) | -9.127(-6) | -4.168(-6) | | | | | |
| | -2268.34 | -2077.20 | -1924.22 | -1799.48 | -1696.27 | -1609.84 | -1536.75 | -1474.48 | -1421.09 | -1375.12 | -1335.42 | | | | | |
| 7 | -1.192(-6) | -5.399(-7) | -7.912(-6) | -2.209(-5) | -3.687(-5) | -4.610(-5) | -4.725(-5) | -4.144(-5) | -3.168(-5) | -2.105(-5) | -1.183(-5) | | | | | |
| | -2702.49 | -2435.48 | -2227.82 | -2062.32 | -1927.88 | -1817.00 | -1724.43 | -1646.40 | -1580.12 | -1523.49 | -1474.92 | | | | | |
| 8 | -9.891(-10) | -1.003(-6) | -2.914(-6) | -5.530(-6) | -9.419(-6) | -1.444(-5) | -1.906(-5) | -2.109(-5) | -1.942(-5) | -1.476(-5) | -9.071(-6) | | | | | |
| | -3312.24 | -2919.90 | -2626.39 | -2399.39 | -2219.33 | -2073.66 | -1953.96 | -1854.37 | -1770.71 | -1699.90 | -1639.65 | | | | | |
| 9 | -2.360(-6) | -6.621(-7) | -3.517(-7) | -3.168(-6) | -4.705(-6) | -3.070(-6) | -8.071(-7) | -1.674(-9) | -2.840(-7) | -5.380(-7) | -3.828(-7) | | | | | |
| | -4227.89 | -3608.92 | -3170.93 | -2845.86 | -2596.04 | -2398.92 | -2240.16 | -2110.24 | -2002.57 | -1912.47 | -1836.55 | | | | | |
| 10 | -1.684(-6) | -4.010(-12) | -3.547(-6) | -1.011(-5) | -1.085(-5) | -5.756(-6) | -1.159(-6) | -1.221(-8) | -7.133(-7) | -1.157(-6) | -8.585(-7) | | | | | |
| | -5746.12 | -4659.89 | -3954.58 | -3461.48 | -3098.78 | -2821.99 | -2604.83 | -2430.80 | -2289.04 | -2172.08 | -2074.66 | | | | | |
| 11 | -1.300(-7) | -5.070(-8) | -3.098(-7) | -8.754(-10) | -1.573(-6) | -7.383(-6) | -1.419(-5) | -1.667(-5) | -1.345(-5) | -7.449(-6) | -2.406(-6) | | | | | |
| | -8710.54 | -6436.23 | -5164.11 | -4354.14 | -3795.35 | -3388.31 | -3080.00 | -2839.62 | -2648.04 | -2492.76 | -2365.30 | | | | | |
| 12 | -1.193(-7) | -8.401(-7) | -1.020(-6) | -3.838(-7) | -6.109(-8) | -8.717(-8) | -6.397(-7) | -2.308(-6) | -4.610(-6) | -6.119(-6) | -5.930(-6) | | | | | |
| | -16920.63 | -10033.47 | -7249.52 | -5748.36 | -4812.87 | -4176.61 | -3717.87 | -3373.19 | -3106.22 | -2894.71 | -2724.24 | | | | | |
| 13 | -3.285(-10) | -2.808(-9) | -5.723(-7) | -2.335(-6) | -2.869(-6) | -1.339(-6) | -9.058(-8) | -1.658(-7) | -4.995(-7) | -3.551(-7) | -5.090(-8) | | | | | |
| | -146274.03 | -21095.53 | -11671.71 | -8216.95 | -6430.32 | -5342.86 | -4614.50 | -4095.13 | -3708.22 | -3410.70 | -3176.50 | | | | | |
| 14 | 1.275(-7) | 3.499(-12) | -1.461(-8) | -6.828(-9) | -4.799(-7) | -1.741(-6) | -2.391(-6) | -1.518(-6) | -2.956(-7) | -5.129(-8) | -7.035(-7) | | | | | |
| | 23822.59 | 709202.75 | -27126.87 | -13720.03 | -9372.08 | -7227.92 | -5956.12 | -5118.25 | -4527.80 | -4091.96 | -3759.41 | | | | | |
| 15 | 3.474(-6) | 1.337(-7) | 9.034(-10) | -1.923(-8) | -6.775(-8) | -6.054(-9) | -1.551(-7) | -8.929(-7) | -1.724(-6) | -1.821(-6) | -1.123(-6) | | | | | |
| | 11442.42 | 21355.11 | 116913.39 | -36404.70 | -16317.81 | -10760.18 | -8164.76 | -6668.36 | -5699.93 | -5026.03 | -4533.47 | | | | | |
| 16 | 4.790(-3) | 3.791(-5) | 2.168(-7) | 4.871(-9) | -9.605(-9) | -9.177(-8) | -1.185(-7) | -3.158(-8) | -2.217(-8) | -2.839(-7) | -7.566(-7) | | | | | |
| | 7723.79 | 11248.19 | 19751.39 | 68460.21 | -52065.08 | -19662.11 | -12437.58 | -9269.05 | -7498.24 | -6373.97 | -5602.06 | | | | | |

| | | | | | | | | | | | |
|----|----------|-----------|-----------|-----------|-----------|------------|-------------|-------------|------------|------------|-------------|
| 17 | 1.858(0) | 3.306(-2) | 3.103(-4) | 6.932(-7) | 7.290(-9) | -2.701(-9) | -8.065(-8) | -1.949(-7) | -1.907(-7) | -7.523(-8) | -6.092(-14) |
| | 5941.88 | 7829.02 | 11178.67 | 18714.76 | 50968.40 | -83108.18 | -24053.06 | -14480.33 | -10577.77 | -8470.16 | -7159.28 |
| 18 | 1.585(2) | 7.977(0) | 1.965(-1) | 2.306(-3) | 6.316(-6) | 1.736(-9) | -3.042(-10) | -4.807(-8) | -1.661(-7) | -2.138(-7) | -1.422(-7) |
| | 4903.40 | 6120.96 | 7993.66 | 11226.26 | 18095.25 | 42353.85 | -168587.34 | -29925.69 | -16979.43 | -12133.22 | -9612.08 |
| 19 | 3.794(3) | 4.669(2) | 3.087(1) | 1.029(0) | 1.583(-2) | 6.989(-5) | 3.748(-8) | -6.648(-13) | -1.758(-8) | -9.418(-8) | -1.740(-7) |
| | 4228.28 | 5103.71 | 6342.67 | 8220.99 | 11386.13 | 17801.95 | 37549.71 | -1172204.18 | -37976.91 | -20058.04 | -13991.34 |
| 20 | 2.259(4) | 7.270(3) | 1.205(3) | 1.060(2) | 4.753(0) | 9.871(-2) | 6.879(-4) | 1.179(-6) | 4.732(-11) | -5.635(-9) | -3.533(-8) |
| | 3758.17 | 4434.20 | 5340.57 | 6612.73 | 8517.18 | 11660.81 | 17788.82 | 34806.08 | 307511.56 | -49330.05 | -23872.58 |
| 21 | 1.641(4) | 2.382(4) | 1.156(4) | 2.667(3) | 3.174(2) | 1.923(1) | 5.465(-1) | 5.818(-3) | 1.747(-5) | 1.230(-9) | -3.575(-9) |
| | 3415.41 | 3964.73 | 4673.99 | 5620.26 | 6938.96 | 8891.94 | 12059.95 | 18039.26 | 33382.34 | 155462.33 | -65854.36 |
| 22 | 6.314(3) | 2.884(3) | 1.737(4) | 1.452(4) | 4.910(3) | 8.114(2) | 6.730(1) | 2.645(0) | 4.164(-2) | 1.868(-4) | 2.359(-8) |
| | 3157.30 | 3621.09 | 4203.70 | 4953.84 | 5950.62 | 7331.52 | 9358.47 | 12599.13 | 18555.67 | 32929.01 | 114273.79 |
| 23 | 4.304(3) | 1.330(4) | 7.397(2) | 6.514(3) | 1.321(4) | 7.198(3) | 1.723(3) | 1.999(2) | 1.097(1) | 2.488(-1) | 1.638(-3) |
| | 2958.46 | 3361.95 | 3858.43 | 4481.28 | 5281.60 | 6341.80 | 7803.85 | 9934.70 | 13301.65 | 19359.17 | 33291.56 |
| 24 | 1.153(4) | 6.189(2) | 7.845(3) | 6.850(3) | 1.611(2) | 7.241(3) | 7.836(3) | 2.921(3) | 4.905(2) | 3.815(1) | 1.238(0) |
| | 2802.89 | 3162.48 | 3597.99 | 4133.75 | 4805.45 | 5667.50 | 6807.24 | 8373.95 | 10645.17 | 14201.37 | 20492.52 |
| 25 | 4.202(3) | 3.598(3) | 7.145(3) | 2.572(2) | 7.475(3) | 2.183(3) | 1.238(3) | 5.540(3) | 3.723(3) | 9.580(2) | 1.084(2) |
| | 2679.98 | 3006.88 | 3397.93 | 3871.85 | 4455.12 | 5186.49 | 6124.96 | 7364.76 | 9065.93 | 11523.45 | 15346.34 |
| 26 | 1.977(1) | 7.398(3) | 6.163(2) | 5.322(3) | 2.760(3) | 1.514(3) | 4.808(3) | 2.948(2) | 1.777(3) | 3.209(3) | 1.412(3) |
| | 2582.36 | 2884.54 | 3242.53 | 3671.35 | 4191.72 | 4832.95 | 5637.91 | 6671.72 | 8038.09 | 9912.36 | 12615.64 |
| 27 | 1.484(3) | 4.986(3) | 7.718(2) | 5.223(3) | 3.525(1) | 4.511(3) | 5.572(2) | 2.041(3) | 2.234(3) | 4.383(0) | 1.479(3) |
| | 2504.79 | 2788.09 | 3121.15 | 3516.52 | 3991.08 | 4568.17 | 5280.84 | 6177.44 | 7331.34 | 8859.19 | 10957.75 |
| 28 | 3.416(3) | 1.707(3) | 2.965(3) | 2.029(3) | 1.838(3) | 2.568(3) | 5.230(2) | 2.692(3) | 1.154(1) | 1.632(3) | 7.285(2) |
| | 2443.34 | 2712.17 | 3026.31 | 3396.59 | 3637.31 | 4367.84 | 5014.94 | 5816.67 | 6828.69 | 8135.54 | 9871.67 |
| 29 | 3.824(3) | 2.087(2) | 3.613(3) | 2.531(2) | 2.968(3) | 4.913(2) | 1.936(3) | 9.046(2) | 7.806(2) | 1.201(3) | 5.754(1) |
| | 2395.01 | 2652.74 | 2952.52 | 3303.91 | 3719.43 | 4215.75 | 4815.49 | 5550.04 | 6464.12 | 7623.31 | 9127.49 |
| 30 | 3.195(3) | 1.995(1) | 2.974(3) | 2.781(1) | 2.597(3) | 1.142(0) | 2.068(3) | 4.155(1) | 1.380(3) | 2.103(2) | 6.493(2) |
| | 2357.39 | 2606.67 | 2895.55 | 3232.74 | 3629.49 | 4100.57 | 4665.78 | 5352.12 | 6197.20 | 7254.81 | 8604.21 |
| 31 | 2.305(3) | 2.409(2) | 2.026(3) | 3.070(2) | 1.738(3) | 2.277(2) | 1.453(3) | 8.840(1) | 1.129(3) | 4.890(0) | 7.531(2) |
| | 2328.50 | 2571.39 | 2852.09 | 3178.66 | 3561.45 | 4013.94 | 4553.95 | 5205.48 | 6001.44 | 6987.97 | 8231.43 |
| 32 | 1.543(3) | 4.285(2) | 1.255(3) | 5.296(2) | 1.017(3) | 4.656(2) | 8.354(2) | 3.016(2) | 6.754(2) | 1.359(2) | 5.045(2) |
| | 2306.65 | 2544.77 | 2819.38 | 3138.08 | 3510.59 | 3949.45 | 4471.12 | 5097.54 | 5858.43 | 6794.83 | 7964.74 |
| 33 | 9.974(2) | 4.879(2) | 7.462(2) | 5.876(2) | 5.588(2) | 5.410(2) | 4.354(2) | 3.999(2) | 3.466(2) | 2.392(2) | 2.653(2) |
| | 2290.41 | 2525.02 | 2795.14 | 3108.09 | 3473.10 | 3902.06 | 4410.49 | 5018.87 | 5754.76 | 6655.76 | 7774.34 |

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