

FINE STRUCTURE RADIATIVE TRANSITIONS IN C II AND C III USING THE BREIT–PAULI *R*-MATRIX METHOD

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Extensive sets of radiative transitions in C II and in C III are obtained using the relativistic Breit–Pauli *R*-matrix (BPRM) method. In comparison with other accurate methods that can be applied to relatively few transitions, the BPRM method enables calculations of a large number of transitions with comparable accuracy for most of them. The present work reports large-scale calculations for two important ions obtaining 127 and 206 bound fine structure energy levels, resulting in 1681 and 4202 dipole allowed and intercombination transitions for C II and C III, respectively. Detailed comparison of the BPRM results is made with those from experimental and theoretical studies, including the relativistic multiconfiguration Dirac–Fock method.

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INTRODUCTION

The Breit–Pauli R -matrix (BPRM) method [1] is being used to calculate a large number of oscillator strengths (f -values) [2–5]. The first large scale application of the BPRM method for the radiative transitions in Fe XXIV and Fe XXV [2] showed very good agreement, within 10%, of the f -values with the most accurate theoretical calculations available. Most of the experimental and theoretical studies for oscillator strengths and transition probabilities (A -values) are focused on a few or a limited number of transitions, whereas various spectral diagnostic models and astrophysical applications, such as plasma opacities, require f - or A -values for a very large number of transitions. Systematic calculations for radiative processes were carried out for most astrophysically abundant atoms and ions under the Opacity Project (OP [6–9]). The datasets obtained under the OP are available electronically through a database, TOPbase [10]. The calculations under the OP were carried out in LS coupling and no relativistic effects were considered. However, fine structure transitions, rather than LS multiplets, are needed for spectral diagnostics in astrophysical and laboratory plasmas.

The Breit–Pauli R -matrix method developed under the Iron Project (IP, [1]) includes relativistic effects in the Breit–Pauli approximation [1, 11, 12] for collisional processes. Recently, the method has been extended to enable close coupling calculations of oscillator strengths (i) including the relativistic effects and (ii) considering a large number of transitions.

The present study investigates the relativistic and electron–electron correlation effects in transitions of two important light ions, C II and C III. These two ions are of particular interest in the diagnostics of a number of astrophysical objects such as in early type stars and nebulae as well as in laboratory plasmas.

THEORY

Provided here is a brief summary of the the basics of the Breit–Pauli R -matrix method. The method for radiative bound-bound and bound-free transitions is derived from atomic collision theory and the coupled channel or close coupling (CC) approximation [1, 6]. The computational method

is based on the powerful R -matrix formalism that enables efficient, accurate, and large-scale calculations of compound (bound and continuum) state wavefunctions of the ($e + \text{ion}$) system at all positive or negative energies.

In the CC approximation, the target (the core ion is referred to as the “target”) is represented by a N -electron system, and the total wavefunction expansion, $\Psi(E)$, of the ($N + 1$)-electron system for any symmetry $SL\pi$ or $J\pi$ is represented in terms of the target wavefunctions as

$$\Psi(E) = A \sum_i \chi_i \theta_i + \sum_j c_j \Phi_j, \quad (1)$$

where χ_i is the target wavefunction in a specific state $S_i L_i \pi_i$ or level $J_i \pi_i$ and θ_i is the wavefunction for the ($N + 1$)th electron in a channel labeled as $S_i L_i \pi_i (J_i \pi_i) k_i^2 \ell_i (SL\pi; J\pi)$; k_i^2 being its incident kinetic energy. The Φ_j 's are the correlation functions of the ($N + 1$)-electron system that account for short range correlation and the orthogonality between the continuum and the bound orbitals.

The Breit–Pauli (BP) Hamiltonian, as employed in the IP work [1], is

$$H_{N+1}^{\text{BP}} = H_{N+1} + H_{N+1}^{\text{mass}} + H_{N+1}^{\text{Dar}} + H_{N+1}^{\text{so}}, \quad (2)$$

where H_{N+1} is the nonrelativistic Hamiltonian,

$$H_{N+1} = \sum_{i=1}^{N+1} \left\{ -\nabla_i^2 - \frac{2Z}{r_i} + \sum_{j>i}^{N+1} \frac{2}{r_{ij}} \right\}, \quad (3)$$

and the additional terms are the one-body mass correction term, the Darwin term, and the spin–orbit term, respectively. However, the two-body terms of the Breit interaction,

$$H^B = \sum_{i>j} [g_{ij}(\text{so} + \text{so}') + g_{ij}(\text{ss}')], \quad (4)$$

representing the spin–spin and the spin–other-orbit interactions are not included in the calculations. The “channels,” characterized by the spin and orbital angular quantum numbers of the ($e + \text{ion}$) system, describe the scattering process of the free electron interacting with the target ion at positive energies. However, at *negative* total energies of the ($e + \text{ion}$) system, when the scattering channels are “closed,” the solutions of the close coupling equations occur at discrete eigenvalues of the ($e + \text{ion}$) Hamiltonian that correspond to pure bound states. In other words,

$$\begin{aligned} E = k^2 > 0 &\rightarrow \text{continuum (scattering) channels} \\ E = -\frac{Z^2}{\nu^2} < 0 &\rightarrow \text{bound states,} \end{aligned} \quad (5)$$

where ν is the effective quantum number relative to the core level.

The BPRM intermediate coupling calculations employ a pair coupling scheme adopted as

$$J_i + l_i = K, \quad K + 1/2 = J, \quad (6)$$

where a set of $SL\pi$ are recoupled to obtain ($e + \text{ion}$) levels with total $J\pi$, followed by diagonalization of the ($N + 1$)-electron Hamiltonian,

$$H_{N+1}^{\text{BP}} \Psi = E \Psi. \quad (7)$$

In terms of the total bound state wavefunctions, the expression for the oscillator strength is proportional to the generalized linestrength (S) defined, in either length (L) form or velocity (V) form, by the equations

$$S_L = \left| \langle \Psi_f | \sum_{j=1}^{N+1} r_j | \Psi_i \rangle \right|^2 \quad (8)$$

and

$$S_V = \omega^{-2} \left| \langle \Psi_f | \sum_{j=1}^{N+1} \frac{\partial}{\partial r_j} | \Psi_i \rangle \right|^2, \quad (9)$$

where ω is the incident photon energy in Rydberg units, and Ψ_i and Ψ_f are the wavefunctions representing the initial and final states, respectively.

Using the transition energy E_{ji} , the oscillator strength f_{ij} is obtained from S as

$$f_{ij} = \frac{E_{ji}}{3g_i} S, \quad (10)$$

and the Einstein A -coefficient A_{ji} in atomic units ($a.u.$) as

$$A_{ji}(a.u.) = \frac{1}{2} \alpha^3 \frac{g_i}{g_j} E_{ji}^2 f_{ij}, \quad (11)$$

where α is the fine structure constant, and g_i, g_j are the statistical weight factors of the initial and final states. In c.g.s. units

$$A_{ji}(s^{-1}) = \frac{A_{ji}(a.u.)}{\tau_0}, \quad (12)$$

where $\tau_0 = 2.4191 \times 10^{-17}$ s is the atomic unit of time.

The lifetime, τ_j , of a level j can be obtained from the transition probabilities of j decaying to the lower levels, i.e., from the A -values, as

$$\tau_j = \frac{1}{A_j(s^{-1})}, \quad (13)$$

where A_j is the total radiative transition probability for the level j , i.e.,

$$A_j = \sum_i A_{ji}. \quad (14)$$

ATOMIC CALCULATIONS

The wavefunction expansion, Eq. (1), for C II consists of 20 levels of the core ion C III with configurations, $2s^2$, $2s2p$, $2p^2$, $2s3s$, $2s3p$, $2s3d$, while the K -shell remains closed. The levels are given in Table A. The table also lists the correlation configurations used in the optimization of the 20 levels in an atomic structure calculation. The correlation term, the second term of Eq. (1), considers all possible $(N + 1)$ -electron configurations formed from the target spectroscopic and correlation configurations added by an electron in the orbital, which include configurations $2p^3$, $3s^2$, $3p^2$, $3d^2$, $4s^2$, $4p^2$.

The eigenfunction expansion for C III consists of 15 levels of C IV of configurations from $1s^22s$ to $1s^24f$ (Table A). The set for the target correlation configurations is also presented in the table. The $(N + 1)$ -electron correlation term of Eq. (1) for C III includes all possible configurations with $2s^2$, $2p^2$, $3s^2$, $3p^2$, $3d^2$ and $4s$, $4p$, $4d$, $4f$.

TABLE A

Energy Levels in Rydbergs of C III (Lefthand Column) and C IV (Righthand Column) in the Eigenfunction Expansion of C II and C III Respectively

Level	E (Ry)	Level	E (Ry)
1 $2s^2$ 1S_0	0.	1 $2s$ $^2S_{1/2}$	0.
2 $2s2p$ $^3P_2^o$	0.47793	2 $2p$ $^2P_{3/2}^o$	0.58860
3 $2s2p$ $^3P_1^o$	0.4774	3 $2p$ $^2P_{1/2}^o$	0.58762
4 $2s2p$ $^3P_0^o$	0.4772	4 $3s$ $^2S_{1/2}$	2.7598
5 $2s2p$ $^1P_1^o$	0.9327	5 $3p$ $^2P_{3/2}^o$	2.9168
6 $2p^2$ 3P_2	1.2530	6 $3p$ $^2P_{1/2}^o$	2.9165
7 $2p^2$ 3P_1	1.2526	7 $3d$ $^2D_{5/2}$	2.9606
8 $2p^2$ 3P_0	1.2523	8 $3d$ $^2D_{3/2}$	2.9606
9 $2p^2$ 1D_2	1.3293	9 $4s$ $^2S_{1/2}$	3.6574
10 $2p^2$ 1S_0	1.6632	10 $4p$ $^2P_{3/2}^o$	3.7209
11 $2s3s$ 3S_1	2.1708	11 $4p$ $^2P_{1/2}^o$	3.7208
12 $2s3s$ 1S_0	2.2524	12 $4d$ $^2D_{5/2}$	3.7393
13 $2s3p$ $^1P_1^o$	2.3596	13 $4d$ $^2D_{3/2}$	3.7393
14 $2s3p$ $^3P_2^o$	2.3668	14 $4f$ $^2F_{7/2}^o$	3.7402
15 $2s3p$ $^3P_1^o$	2.3667	15 $4f$ $^2F_{5/2}^o$	3.7402
16 $2s3p$ $^3P_0^o$	2.3666		
17 $2s3d$ 3D_3	2.4606		
18 $2s3d$ 3D_2	2.4605		
19 $2s3d$ 3D_1	2.4605		
20 $2s3d$ 1D_2	2.5195		

Note. The list of spectroscopic and correlation configurations, and the scaling parameter (λ) for each orbital is as follows. For C III, Spectroscopic: $2s^2$, $2s2p$, $2p^2$, $2s3s$, $2s3p$, $2s3d$; Correlation: $2p3s$, $2p3p$, $2p3d$, $3s3p$, $3s3d$, $2s4s$, $2s4p$, $4s4p$; λ : 1.42(1s), 1.4(2s), 1.125(2p), 1.(3s), 1(3p), 1(3d), 3.3(4s), 3(4p). For C IV, Spectroscopic: $1s$, $2p$, $3s$, $3p$, $3d$, $4s$, $4p$, $4d$, $4f$; Correlation: $1s2s^2$, $1s2p^2$, $1s3s^2$, $1s3p^2$, $1s3d^2$, $1s2s2p$, $1s2s3s$, $1s2s3p$, $1s2s3d$, $1s2p3s$, $1s2p3d$; λ : 1.30117(1s), 0.99782(2s), 0.87558(2p), 0.98747(3s), 0.86738(3p), 0.80564(3d), 0.98598(4s), 0.86603(4p), 0.79571(4d), 0.77675(4f).

The target or core energies and wavefunctions of both the ions were obtained from atomic structure calculations using the program SUPERSTRUCTURE [14]. The spectroscopic and correlation configurations and the values of the scaling parameter (λ) in the Thomas–Fermi potential for each orbital of C III and C IV in the calculations are in Table A. Although the calculated target energies agree within a few percent with the measured values, the calculated level energies are replaced with the observed ones [15] in the BPRM calculations for improved accuracy.

The computations are carried out using the BPRM packages of codes [12]. The R -matrix basis set within the R -matrix boundary has 12 terms for C II and 30 terms for C III respectively. The intermediate coupling calculations are carried out on recoupling the LS symmetries in a pair-coupling representation. The $(e + \text{core})$ Hamiltonian matrix is diagonalized for each resulting $J\pi$. The bound levels are scanned with an energy mesh of 0.001 Rydberg (Ry) to avoid any missing levels. The fine mesh increases the computation considerably.

In the BPRM method, the energy levels are initially identified with the quantum number J and parity π only. This is insufficient information for unique and spectroscopic identification of a level. An identification scheme, based on the quantum defect analysis and dominant percentage contributions of the channel wavefunctions of a level, as developed by Nahar and Pradhan [3] has been adopted for complete spectroscopic notation of the levels. Each level is associated with a number of collision channels where the dominant channels determine the proper configurations, LS terms and fine structure levels of the core and the outer electrons. The levels are finally designated with possible identification of $C_i(S_iL_i\pi_i)J_i nl J(SL)\pi$ where C_i , $S_iL_i\pi_i$, J_i are the configuration, LS term and parity, and total angular momentum of the core or target, nl are the principal and orbital quantum numbers of the outer or the valence electron, and J and $SL\pi$ are the total angular momentum, possible LS term and parity of the $(N + 1)$ -electron system. Equivalent electron levels are identified with a possible configuration and term as explained in Ref. [3].

RESULTS AND DISCUSSION

Large sets of fine structure energy levels and oscillator strengths are reported for C II and C III obtained using the Breit–Pauli R -matrix method. The advantage of the BPRM method, as mentioned before, is the capability of obtaining a large number of accurate transition probabilities for various spectral diagnostic and modeling applications. The energies and oscillator strengths for each ion are discussed separately

and are compared with experimental and other theoretical calculations in the following subsections.

Energies and Oscillator Strengths of C II

The present results for C II include fine structure energy levels and transitions among $1/2 \leq J \leq 17/2$ of even and odd parities with $n \leq 10$ and $l \leq 9$, $2S + 1 = 2, 4$ and $L \leq 10$.

The calculated set of energies includes 77 observed levels of C II. The eight highly excited observed levels of the terms $2s2p(^3P^o)3d(^4D, F^o)$ are not obtained. A sample comparison between the calculated and observed [15] energies is presented in Table B. BPRM energies agree to within less than 5% with 61 observed levels. The largest difference is less than 9% except for two levels of $2s2p(^3P^o)3s$; while the two quartets of the configuration are in less than 1% agreement with the observed energies, the two doublet levels show 19% difference, indicating either that the doublets are highly mixed, or the level cannot be properly identified. One reason could be that the doublet term is not well represented by correlation configurations, although the present set includes most of the dominant configurations (Table A).

Table C makes detailed comparison of the present C II transition probabilities (A -values) and lifetimes (τ) with other measurements and calculations. The transitions are specified as higher level (index k) to lower level (index i) followed by gf - and A -values. The sum of A -values and τ 's are given below the set of transitions. The columns n_k and n_i are the energy level indices for the symmetries J_k and J_i , respectively.

The intercombination transitions of $2s2p(^4P) - 2s^22p(^2P^o)$ have been studied by a number of investigators when the radiative decay rates and the lifetimes of the three levels of $2s2p(^4P_{1/2,3/2,5/2})$ were obtained. The five possible intercombination E1 transitions, $2s2p(^4P_{1/2,3/2,5/2}) - 2s^22p(^2P^o_{1/2,3/2})$ with $\Delta J = 0, \pm 1$, correspond to very weak oscillator strengths. The measured values are usually available as the sum of A -values for a level. Present BPRM decay rates are compared with those measured by Smith et al. [16], Trabert et al. [17], and Fang et al. [18] and from other theoretical calculations [19–23]. For the two transitions $^4P_{3/2} - ^2P^o_{1/2,3/2}$, the present BPRM sum of rates are about 23% lower than the measured value of Trabert et al. [17], Galavis et al. [23] are about 23% higher, and the Froese Fischer value [22] is in good agreement. The A -values from Froese Fischer, who studied only these weak transitions, were obtained employing the multiconfiguration Hartree–Fock method in the Breit–Pauli approximation. Galavis et al. [23] have considered a relatively larger number

TABLE B
Comparison of Absolute Calculated BPRM Energies (E_c) of C II and C III with the Observed Values (E_o) in Rydbergs

Level	J	E_o (Ry)	E_c (Ry)	
C II: $N_b = 127$				
$2s2(1S)2p$	$^2P^o$	1.5	-1.79160	-1.78793
$2s2(1S)2p$	$^2P^o$	0.5	-1.79210	-1.78850
$2s2p2$	4P	2.5	-1.39980	-1.39802
$2s2p2$	4P	1.5	-1.40010	-1.39835
$2s2p2$	4P	0.5	-1.40030	-1.39855
$2s2p2$	2D	2.5	-1.10930	-1.09567
$2s2p2$	2D	1.5	-1.10930	-1.09569
$2s2p2$	2S	0.5	-0.91282	-0.87706
$2s2p2$	2P	1.5	-0.78368	-0.75481
$2s2p2$	2P	0.5	-0.78406	-0.75522
$2s2(1S)3s$	2S	0.5	-0.73017	-0.72630
$2s2(1S)3p$	$^2P^o$	1.5	-0.59167	-0.59837
$2s2(1S)3p$	$^2P^o$	0.5	-0.59178	-0.59847
$2p3$	$^4S^o$	1.5	-0.49789	-0.46198
$2s2(1S)3d$	2D	2.5	-0.46578	-0.47216
$2s2(1S)3d$	2D	1.5	-0.46579	-0.47218
$2p3$	$^2D^o$	2.5	-0.42103	-0.39157
$2p3$	$^2D^o$	1.5	-0.42098	-0.39160
$2s2(1S)4s$	2S	0.5	-0.35931	-0.35940
$2s2(1S)4p$	$^2P^o$	1.5	-0.31110	-0.31080
$2s2(1S)4p$	$^2P^o$	0.5	-0.31116	-0.31086
$2s2p(3P^o)3s$	$^4P^o$	2.5	-0.27000	-0.26759
$2s2p(3P^o)3s$	$^4P^o$	1.5	-0.27041	-0.26801
$2s2p(3P^o)3s$	$^4P^o$	0.5	-0.27062	-0.26825
$2s2(1S)4d$	2D	2.5	-0.26007	-0.26004
C III: $N_b = 206$				
$2s2$	1S	0	-3.51970	-3.51280
$2s2p$	$^3P^o$	2	-3.04180	-3.03211
$2s2p$	$^3P^o$	1	-3.04230	-3.03261
$2s2p$	$^3P^o$	0	-3.04250	-3.03287
$2s2p$	$^1P^o$	1	-2.58700	-2.56307
$2p2$	3P	2	-2.26670	-2.24401
$2p2$	3P	1	-2.26710	-2.24450
$2p2$	3P	0	-2.26740	-2.24475
$2p2$	1D	2	-2.19040	-2.16887
$2p2$	1S	0	-1.85640	-1.80983
$2s3s$	3S	1	-1.34890	-1.34654
$2s3s$	1S	0	-1.26730	-1.26290
$2s3p$	$^1P^o$	1	-1.16010	-1.15559
$2s3p$	$^3P^o$	2	-1.15290	-1.14939
$2s3p$	$^3P^o$	1	-1.15300	-1.14950
$2s3p$	$^3P^o$	0	-1.15310	-1.14956
$2s3d$	3D	3	-1.05910	-1.05739
$2s3d$	3D	2	-1.05920	-1.05743
$2s3d$	3D	1	-1.05920	-1.05745
$2s3d$	1D	2	-1.00020	-0.99594
$2p3s$	$^3P^o$	2	-0.71009	-0.70194
$2p3s$	$^3P^o$	1	-0.71072	-0.70254
$2p3s$	$^3P^o$	0	-0.71101	-0.70283
$2s4s$	3S	1	-0.69971	-0.69803
$2p3s$	$^1P^o$	1	-0.69470	-0.68864
$2s4s$	1S	0	-0.67907	-0.67759

Note. N_b is the total number of levels obtained.

TABLE C
Comparison of Present BPRM gf and A -Values and Lifetimes (τ_o) for C II with Other Theoretical and Experimental (Asterisks) Values

$Conf_k$	$2J_k : n_k$	$Conf_i$	$2J_i : n_i$	gf_{ik} P	$A_{ki}(s^{-1})$ P	O
$2s2p^2(^4P)^e$	1 : 1	$-2s^22p(^2P^o)$	1 : 1	4.26(-8)	52.5	42.5[19], 55.3[20], 62.54[22], 74.4[21], 71.91[23]
$2s2p^2(^4P)^e$	1 : 1	$-2s^22p(^2P^o)$	3 : 1	2.19(-8)	53.9	40.2[19], 65.5[20], 69.57[22], 77.8[21], 81.89[23]
$\Sigma A_{ki}(s^{-1}) = 106.4(P), 132.2[22], 153.8[23], 125.8(.9)*[17], 130(5.5)*[16], 146.4(8.2, -9.2)*[18]$						
$\tau_o(ms) = 9.40(P), 6.50[23], 7.95(.07)*[17], 7.69(.31)*[16]$						
$2s2p^2(^4P^e)$	3 : 1	$-2s^22p(^2P^o)$	1 : 1	1.94(-9)	1.19	1.01[19], 1.71[20], 1.44[22], 1.70[21], 1.87[23]
$2s2p^2(^4P^e)$	3 : 1	$-2s^22p(^2P^o)$	3 : 1	9.24(-9)	11.4	8.11[19], 5.24[20], 9.43[22], 12.4[21], 10.22[23]
$\Sigma A_{ki}(s^{-1}) = 12.6(P), 12.09[23], 9.25[22], 11.6(08, -1.7)*[18]$						
$\tau_o(ms) = 79.4(P), 82.7[23], 108.1[22], 86.2(-6.5)*[18], 104.1(.5)*[17], 110(10)*[16]$						
$2s2p^2(^4P^e)$	5 : 1	$-2s^22p(^2P^o)$	3 : 1	4.18(-8)	34.4	34.4[19], 43.2[20], 53.9[21], 50.31[23]
$\Sigma A_{ki}(s^{-1}) = 34.4(P), 46.1[22], 45.37(.17)*[17], 50(2.5)*[16], 51.2(2.6, -3.5)*[18]$						
$\tau_o(ms) = 29.1(P), 19.9[23], 21.7[22], 22.05(.07)*[17], 20(1)*[16]$						
$2s2p^2(^2S^e)$	1 : 2	$-2s^22p(^2P^o)$	1 : 1	0.1330	8.26(8)	
$2s2p^2(^2S^e)$	1 : 2	$-2s^22p(^2P^o)$	3 : 1	0.1314	1.63(9)	
$\Sigma A_{ki}(s^{-1}) = 2.456(9) \quad \tau_o(ns) = 0.41(P), .42[25], .46[23], .62[24], 44(.02)*[26], 41(.04)*[27], .48(.03)*[40]$						
$2s2p^2(^2P^e)$	1 : 3	$-2s^22p(^2P^o)$	1 : 1	0.335	2.73(9)	
$2s2p^2(^2P^e)$	1 : 3	$-2s^22p(^2P^o)$	3 : 1	0.849	1.38(9)	
$\Sigma A_{ki}(s^{-1}) = 4.116(9) \quad \tau_o(ns) = 0.243(P), .234[25], .239[23], .343[24], LS : 0.25(.01)*[26], .25(.03)*[40]$						
$2s2p^2(^2P^e)$	3 : 3	$-2s^22p(^2P^o)$	1 : 1	0.1681	6.86(8)	
$2s2p^2(^2P^e)$	3 : 3	$-2s^22p(^2P^o)$	3 : 1	0.4207	3.43(9)	
$\Sigma A_{ki}(s^{-1}) = 4.116(9) \quad \tau_o(ns) = 0.243(P), .234[25], .239[23], .343[24], LS : 0.25(.01)*[26], .25(.03)*[40]$						
$2p^3(^2D^o)$	3 : 4	$-2s2p^2(^2P)$	1 : 3	0.0809	4.28(7)	
$2p^3(^2D^o)$	3 : 4	$-2s2p^2(^2D)$	3 : 2	0.1070	4.07(8)	
$2p^3(^2D^o)$	3 : 4	$-2s2p^2(^2D)$	5 : 2	0.0081	4.62(7)	
$\Sigma A_{ki}(s^{-1}) = 5.044(8) \quad \tau_o(ns) = 1.982(P), 1.87[25], 2.04[23], 1.36[24], LS : 1.7(.15)*[30], 1.85(.2)*[31]$						
$2p^3(^2D^o)$	5 : 1	$-2s2p^2(^2D)$	3 : 2	0.0120	3.04(7)	
$2p^3(^2D^o)$	5 : 1	$-2s2p^2(^2P)$	3 : 3	0.0725	5.10(7)	
$2p^3(^2D^o)$	5 : 1	$-2s2p^2(^2D)$	5 : 2	0.1114	4.24(8)	
$\Sigma A_{ki}(s^{-1}) = 5.054(8) \quad \tau_o(ns) = 1.979(P), 1.87[25], 2.04[23], 1.37[24], LS : 1.7(.15)*[30], 1.85(.2)*[31]$						
$2p^3(^2P^o)$	1 : 5	$-2s2p^2(^2P)$	1 : 3	0.0712	1.60(8)	
$2p^3(^2P^o)$	1 : 5	$-2s2p^2(^2D)$	3 : 2	0.1196	1.40(9)	
$\Sigma A_{ki}(s^{-1}) = 1.678(9) \quad \tau_o(ns) = 0.596(P), .550[25], .456[23], .517[24], LS : 0.48(.02)*[30], 0.51(.06)*[31]$						
$2p^3(^2P^o)$	3 : 7	$-2s2p^2(^2D)$	3 : 2	0.0240	1.41(8)	
$2p^3(^2P^o)$	3 : 7	$-2s2p^2(^2P)$	3 : 3	0.0895	2.01(8)	
$2p^3(^2P^o)$	3 : 7	$-2s2p^2(^2D)$	5 : 2	0.1436	1.26(9)	
$\Sigma A_{ki}(s^{-1}) = 1.676(9) \quad \tau_o(ns) = 0.596(P), .550[25], .456[23], .517[24], LS : 0.48(.02)*[30], 0.51(.06)*[31]$						
$2s^23s(^2S)$	1 : 4	$-2s^22p(^2P^o)$	1 : 1	0.0059	5.38(7)	
$2s^23s(^2S)$	1 : 4	$-2s^22p(^2P^o)$	3 : 1	0.0054	9.87(7)	
$\Sigma A_{ki}(s^{-1}) = 1.525(8) \quad \tau_o(ns) = 6.557(P), 2.82[25], LS : 2.4(.3)*[26], 2.0(.2)*[27]$						
$2s^24s(^2S)$	1 : 5	$-2s^22p(^2P^o)$	1 : 1	5.645(-3)	9.31(7)	
$2s^24s(^2S)$	1 : 5	$-2s^23p(^2P^o)$	1 : 2	1.411(-1)	6.13(7)	
$2s^24s(^2S)$	1 : 5	$-2s^22p(^2P^o)$	3 : 1	5.662(-3)	1.87(8)	
$2s^24s(^2S)$	1 : 5	$-2s^23p(^2P^o)$	3 : 2	1.412(-1)	1.22(8)	
$\Sigma A_{ki}(s^{-1}) = 4.634(8) \quad \tau_o(ns) = 2.16(P), 2.04[25], LS : 2.1(.1)*[30], 1.9(.1)*[26]$						

TABLE C—Continued

$Conf_k$	$2J_k : n_k$	$Conf_i$	$2J_i : n_i$	gf_{ik} P	$A_{ki}(s^{-1})$ P	O
$2s^25s(^2S)$	1 : 6	$-2s^22p(^2P^o)$	1 : 1	2.180(-3)	4.37(7)	
$2s^25s(^2S)$	1 : 6	$-2s^23p(^2P^o)$	1 : 2	2.201(-2)	2.54(7)	
$2s^25s(^2S)$	1 : 6	$-2s^22p(^2P^o)$	3 : 1	2.186(-3)	8.76(7)	
$2s^25s(^2S)$	1 : 6	$-2s^23p(^2P^o)$	3 : 2	2.202(-2)	5.09(7)	
$2s^25s(^2S)$	1 : 6	$-2s^24p(^2P^o)$	3 : 5	1.995(-1)	3.12(7)	
$\Sigma A_{ki}(s^{-1}) = 2.595(8)$	$\tau_o(ns) = 3.85(P), 3.81[25],$	$LS : 3.7(.2)*[26]$				
$2s^23p(^2P^o)$	1 : 2	$-2s2p(^2S)$	1 : 2	8.144(-2)	6.742(7)	
$2s^23p(^2P^o)$	1 : 2	$-2s^23s(^2S)$	1 : 4	2.214(-1)	3.413(7)	
$2s^23p(^2P^o)$	1 : 2	$-2s2p(^2D)$	3 : 2	1.079(-2)	4.647(7)	
$\Sigma A_{ki}(s^{-1}) = 1.480(8)$	$\tau_o(ns) = 6.755(P), 9.22[25],$	$LS : 8.9(.3)*[30], 8.9(.4)*[26]$				
$2s^23p(^2P^o)$	3 : 2	$-2s2p(^2S)$	1 : 2	1.630(-1)	6.75(7)	
$2s^23p(^2P^o)$	3 : 2	$-2s^23s(^2S)$	1 : 4	4.434(-1)	3.42(7)	
$2s^23p(^2P^o)$	3 : 2	$-2s2p(^2D)$	5 : 2	1.294(-2)	4.18(7)	
$\Sigma A_{ki}(s^{-1}) = 1.482(8)$	$\tau_o(ns) = 6.46(P), 9.22[25],$	$LS : 8.9(.3)*[30], 8.9(.4)*[26]$				
$2s^24p(^2P^o)$	1 : 3	$-2s^23s(^2S)$	1 : 4	1.619(-2)	2.28(7)	
$2s^24p(^2P^o)$	1 : 3	$-2s2p(^2D)$	3 : 2	1.442(-2)	1.48(8)	
$2s^24p(^2P^o)$	1 : 3	$-2s^23d(^2D)$	3 : 4	8.488(-2)	3.26(7)	
$\Sigma A_{ki}(s^{-1}) = 2.221(8)$	$\tau_o(ns) = 4.50(P), 4.36[25],$	$LS : 3.8(.2)*[26]$				
$2s^24p(^2P^o)$	3 : 5	$-2s^23s(^2S)$	1 : 4	3.211(-2)	2.27(7)	
$2s^24p(^2P^o)$	3 : 5	$-2s2p(^2D)$	3 : 2	2.876(-3)	1.47(7)	
$2s^24p(^2P^o)$	3 : 5	$-2s2p(^2D)$	5 : 2	1.719(-2)	1.32(8)	
$2s^24p(^2P^o)$	3 : 5	$-2s^23d(^2D)$	5 : 3	1.018(-1)	2.94(7)	
$\Sigma A_{ki}(s^{-1}) = 2.064(8)$	$\tau_o(ns) = 4.84(P), 4.36[25],$	$LS : 3.8(.2)*[26]$				
$2s^25p(^2P^o)$	1 : 6	$-2s2p(^2D)$	3 : 2	1.063(-2)	1.43(8)	
$\Sigma A_{ki}(s^{-1}) = 2.171(8)$	$\tau_o(ns) = 4.61(P), 4.79[25],$	$LS : 5.2(.3)*[30], 5.2(.3)*[26]$				
$2s^25p(^2P^o)$	3 : 8	$-2s2p(^2P)$	3 : 3	1.433(-2)	3.99(7)	
$2s^25p(^2P^o)$	3 : 8	$-2s2p(^2D)$	5 : 2	1.289(-2)	1.30(8)	
$\Sigma A_{ki}(s^{-1}) = 2.189(8)$	$\tau_o(ns) = 4.57(P), 4.79[25],$	$LS : 5.2(.3)*[30], 5.2(.3)*[26]$				
$2s^23d(^2D^e)$	3 : 4	$-2s^22p(^2P^o)$	1 : 1	3.471(-1)	2.45(9)	
$2s^23d(^2D^e)$	3 : 4	$-2s22p(^2P^o)$	3 : 1	3.476(-2)	4.91(8)	
$\Sigma A_{ki}(s^{-1}) = 2.983(9)$	$\tau_o(ns) = .335(P), .348[25],$	$LS : .34(.01)*[26]$				
$2s^23d(^2D^e)$	5 : 3	$-2s^22p(^2P^o)$	3 : 1	3.123(-1)	2.94(9)	
$\Sigma A_{ki}(s^{-1}) = 2.982(9)$	$\tau_o(ns) = .335(P), .348[25],$	$LS : .34(.01)[26]$				
$2s^24d(^2D)$	3 : 5	$-2s^22p(^2P^o)$	1 : 1	1.148(-1)	1.08(9)	
$2s^24d(^2D)$	3 : 5	$-2s^22p(^2P^o)$	3 : 1	1.149(-2)	2.16(8)	
$\Sigma A_{ki}(s^{-1}) = 1.361(9)$	$\tau_o(ns) = .735(P), .723[25],$	$LS : .73(.03)*[30], 0.75(.03)*[26]$				
$2s^24d(^2D)$	5 : 4	$-2s^22p(^2P^o)$	3 : 1	1.033(-1)	1.30(9)	
$\Sigma A_{ki}(s^{-1}) = 1.361(9)$	$\tau_o(ns) = .735(P), .723[25],$	$LS : .73(.03)*[30], 0.75(.03)*[26]$				
$2s^24f(^2F^o)$	5 : 3	$-2s^23d(^2D)$	3 : 4	8.766(-1)	2.14(8)	
$\Sigma A_{ki}(s^{-1}) = 2.456(8)$	$\tau_o(ns) = 4.07(P), 4.07[25],$	$LS : 3.8(.2)*[30]$				
$2s^24f(^2F^o)$	7 : 1	$-2s^23d(^2D)$	5 : 3	8.349(-1)	2.29(8)	
$\Sigma A_{ki}(s^{-1}) = 2.453(8)$	$\tau_o(ns) = 3.86(P), 4.08[25],$	$LS : 3.8(.2)*[30]$				
$2s^25f(^2F^o)$	5 : 4	$-2s2p(^2D)$	3 : 2	2.477(-3)	1.19(7)	
$2s^25f(^2F^o)$	5 : 4	$-2s^23d(^2D)$	3 : 4	1.557(-1)	7.72(7)	
$2s^25f(^2F^o)$	5 : 4	$-2s^24d(^2D)$	3 : 5	7.287(-1)	3.80(7)	
$\Sigma A_{ki}(s^{-1}) = 1.362(8)$	$\tau_o(ns) = 7.34(P), 7.57[25],$	$LS : 7.2(.4)*[30]$				
$2s^25f(^2F^o)$	7 : 2	$-2s^23d(^2D)$	5 : 3	1.482(-1)	8.27(7)	
$2s^25f(^2F^o)$	7 : 2	$-2s^24d(^2D)$	5 : 4	6.942(-1)	4.07(7)	
$\Sigma A_{ki}(s^{-1}) = 1.362(8)$	$\tau_o(ns) = 7.34(P), 7.57[25],$	$LS : 7.2(.4)*[30]$				

Note. For the multiplets starting with $2p^3-2s2p^2$, only the most dominant transitions instead of the complete set are given. The notation "P" means present, "O" means others, and a(b) means $a \times 10^b$.

of transitions among the $n = 2$ levels in their atomic structure calculations including relativistic effects in the Breit–Pauli approximation. In contrast to the present calculations, both those other calculations include the two-body Breit interaction terms which can be important for very weak transitions. The sum of present BPRM decay rates for the other two transitions, ${}^4P_{3/2-2}P_{1/2,3/2}^o$, agrees closely with the measured value by Fang et al. [18] and with Galavis et al., but is higher than that by Froese Fisher which agrees with other experimental values. The present A -value for the last ${}^4P_{5/2-2}P_{3/2}^o$ transition is much lower than the experimental values and those by Froese Fischer and Galavis et al. It is possible that strong relativistic mixing of the level ${}^4P_{5/2}$ with the $2s2p^2({}^2D_{5/2})$ has reduced the transition probability in the present calculations. The differences between Froese Fischer [22] and Galavis et al. [23] for these transitions indicate that the effect of the two-body Breit interaction terms may not be significant compared to the electron-electron correlation effects.

Among the other comparisons, the present BPRM lifetimes for the $2s2p^2({}^2S, {}^2P)$ levels, due to dipole allowed transitions to $2s^22p({}^2P^o)$, agree with measured values and with those by Galavis et al., but those by Safronova et al. [24] are relatively higher. Safronova et al. present transition rates for $n = 2$ levels using relativistic many body perturbation theory. The largest set of LS multiplet oscillator strengths for C II was calculated by Fernley et al. [25] under the OP. The non-relativistic calculations were carried out using a six-state wavefunction expansion of configurations $2s^2$, $2s2p$, $2p^2$. Compared to the OP work, the present data result from a larger basis of 12 states with additional configurations, $2s3s$, $2s3p$, $2s3d$. The OP results are used for comparison here as most of the lifetimes are measured for LS terms, and also present the only other set of f -values with higher n levels. Present lifetimes for the $2s2p^2({}^2S, {}^2P)$ states are in good agreement with the measured as well as with the OP values.

The available lifetimes for the levels of C II from other sources are longer and correspond to a number of transitions. For brevity, only the most dominant transitions for each term are listed in Table C, although the sum of A -values includes all possible transitions. Present lifetimes for the $2p^3({}^2D^o)$ levels are within the uncertainties of the measured values, while for $2p^3({}^2P^o)$ they are somewhat higher than the measured values. The OP lifetimes [25] for the $2p^3({}^2P^o, {}^2D^o)$ states are comparable to the present values.

Both the OP [25] and the present lifetimes agree well with the measured lifetimes for $2s^24s({}^2S)$ and $2s^25s({}^2S)$ states. However, the OP lifetime for $2s^23s({}^2S)$ agrees closely with experiment while the present value shows large disagreement with a much longer lifetime. The BPRM lifetime for

$2s^23p({}^2P^o)$ levels are lower than the measured values which are in good agreement with the OP lifetime. However, both the present and OP lifetimes for $2s^24p({}^2P^o)$ and $2s^25p({}^2P^o)$ levels agree with each other, but are respectively somewhat higher and lower than the measured values for the former and the latter. Present work has included a larger wavefunction expansion with more correlation. Therefore the reason for these few discrepancies is not obvious. However, we find good agreement between the present theory and experiment for the lifetimes of $2s^23d$, $2s^24d$, $2s^25d$, $2s^24f$, and $2s^25f$ levels.

We have obtained a total of 127 fine structure energy levels for C II. The complete lists of energies are available electronically (at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>) with spectroscopic identification both in $J\pi$ order for various astrophysical and plasma applications, and in LS multiplet order with effective quantum numbers for spectroscopic diagnostics (e.g., [5]). Tables Ia and Ib are samples of the energies in these two formats.

The total number of oscillator strengths (f -values) obtained for fine structure transitions in C II is 1681. The complete table (at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>) contains gf -values along with the level energies, linestrengths (S), and transition probabilities (A -values). Table II presents a sample of the complete file. These transitions are identified spectroscopically by comparing the energy level indices with those in the energy level Table Ia.

A part of the oscillator strength data has been reprocessed for improved accuracy and unique spectroscopic identification for ease of application. The observed transition energies are measured with less uncertainty than the calculated ones, and hence use of the former improves the accuracy of f and A values slightly. The observed energies are used with the energy independent line strength (S) obtained in the BPRM calculations (Eqs. (10) and (11)). The reprocessed set consists of 860 transitions for C II with spectroscopic notation similar to the widely used NIST compilations available through the National Institute of Standards and Technology (NIST). The oscillator strengths are ordered in LS multiplets. It may be noted that while statistical averaging for a LS multiplet can be carried out for dipole allowed transitions, no such averaging can be done for the fine structure components of intercombination transitions. Sample results are presented in Table III. The complete table is available electronically.

Energies and Oscillator Strengths of C III

The present results for C III include fine structure energy levels and transitions among levels of $0 \leq J \leq 10$ of even and odd parities with $n \leq 10$ and $l \leq 9$, $2S + 1 = 1, 3$ and $L \leq 11$.

TABLE D

Comparison of Present BPRM gf -, A -Values and Lifetimes (τ_o) for C III with Other Theoretical and Experimental (Asterisk) Values

$Conf_k$	$2J_k : n_k$	$Conf_i$	$2J_i : n_i$	gf_{ik}		$A_{ki}(s^{-1})$ P	O
				P	O		
$1s^2 2s 2p(^3P^o)$	2 : 1	$-1s^2 2s^2(^1S)$	0 : 1	2.05(-7)	1.93(-7)[39]	125	120.9(7)*[34], 102.94(14)*[35], 102.9(15)[37]
$\Sigma A_{ki}(s^{-1}) = 1.25(2) \quad \tau_o(ms) = 8.0(P), 8.271(.4)*[34], 9.714(.013)*[35]$							
$1s^2 2s 2p(^1P^o)$	2 : 2	$-1s^2 2s^2(^1S)$	0 : 1	0.767	.75(.03)*[29], .758(4)[37], .76[39], .797[42], .794[41]	1.89(9)	
$\Sigma A_{ki}(s^{-1}) = 1.79(9) \quad \tau_o(ns) = 0.559(P), .532[43], 0.57(.02)*[26]$							
$1s^2 2p^2(^1S)$	0 : 3	$-1s^2 2s 2p(^3P^o)$	2 : 1	2.82(-8)		9.54(2)	
$1s^2 2p^2(^1S)$	0 : 3	$-1s^2 2s 2p(^1P^o)$	2 : 2	0.167	0.152(.009)*[26], 0.225[42], .172[41]	2.15(9)	
$\Sigma A_{ki}(s^{-1}) = 2.15(9) \quad \tau_o(ns) = 0.465(P), .417[43], .51(.03)*[26], .56(.03)*[40], .44(.04)*[27], .39(.04)*[28]$							
$1s^2 2p^2(^1D)$	4 : 2	$-1s^2 2s 2p(^3P^o)$	2 : 1	4.88(-6)		1.71(4)	
$1s^2 2p^2(^1D)$	4 : 2	$-1s^2 2s 2p(^1P^o)$	2 : 2	0.1815	0.183(.005)*[26]	1.38(8)	
$1s^2 2p^2(^1D)$	4 : 2	$-1s^2 2s 2p(^3P^o)$	4 : 1	4.85(-6)		2.82(4)	
$\Sigma A_{ki}(s^{-1}) = 1.38(8) \quad \tau_o(ns) = 7.24(P), 7.45[43], 7.2(.2)*[26], 6.9(.2)*[30]$							
$1s^2 2s 3s(^1S)$	0 : 4	$-1s^2 2s 2p(^3P^o)$	2 : 1	8.94(-9)	1.50(-7)[39]	6.79	
$1s^2 2s 3s(^1S)$	0 : 4	$-1s^2 2s 2p(^1P^o)$	2 : 2	0.0189	.019(.002)*[27], .022(.002)*[33], .022[39]	7.93(8)	
$\Sigma A_{ki}(s^{-1}) = 7.93(8) \quad \tau_o(ns) = 1.26(P), 1.35[43], 1.17(.05)*[26], 1.08(.1)*[33], 1.25(.13)*[27]$							
$1s^2 2s 3p(^3P^o)$	0 : 2	$-1s^2 2p^2(^3P)$	2 : 1	6.01(-5)		1.80(6)	
$1s^2 2s 3p(^3P^o)$	0 : 2	$-1s^2 2s 3s(^3S)$	2 : 2	7.77(-2)		7.18(7)	
$\Sigma A_{ki}(s^{-1}) = 7.36(7) \quad \tau_o(ns) = 13.59(P), 13.3[43], LS: 11.6(.3)*[30], 15.1(.5)*[32]$							
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2s^2(^1S)$	0 : 1	1.02(-4)	5.98(-5)[39]	1.53(6)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2s 3s(^3S)$	0 : 2	1.84(-4)		5.79(5)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2p^2(^1S)$	0 : 3	1.06(-5)		1.41(4)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2s 3s(^1S)$	0 : 4	1.63(-4)		5.71(3)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2p^2(^3P)$	2 : 1	4.50(-5)		4.48(5)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2s 3s(^3S)$	2 : 2	2.33(-1)		7.19(7)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2p^2(^3P)$	4 : 1	4.51(-5)		7.49(5)	
$1s^2 2s 3p(^3P^o)$	2 : 4	$-1s^2 2p^2(^1D)$	4 : 2	1.31(-5)		1.89(5)	
$\Sigma A_{ki}(s^{-1}) = 7.545(7) \quad \tau_o(ns) = 13.25(P), 13.3[43], LS: 11.6(.3)*[30], 15.1(.5)*[32]$							
$1s^2 2s 3p(^3P^o)$	4 : 2	$-1s^2 2p^2(^3P)$	2 : 1	7.78(-5)		4.65(5)	
$1s^2 2s 3p(^3P^o)$	4 : 2	$-1s^2 2s 3s(^3S)$	2 : 2	3.89(-1)		7.20(7)	
$1s^2 2s 3p(^3P^o)$	4 : 2	$-1s^2 2p^2(^3P)$	4 : 1	1.37(-4)		1.37(6)	
$1s^2 2s 3p(^3P^o)$	4 : 2	$-1s^2 2p^2(^1D)$	4 : 2	1.63(-9)		1.41(1)	
$\Sigma A_{ki}(s^{-1}) = 7.38(7) \quad \tau_o(ns) = 13.35(P), 13.3[43], LS: 11.6(.3)*[30], 15.1(.5)*[32]$							

Note. "P" represents present and "O" for others. The notation "P" means present, "O" means others and a(b) means $a \times 10^b$.

The calculated set of energy levels include 115 observed levels. The BPRM energies agree to less than 1% with 88 of the observed levels; the largest difference is about 3.6%. Sample comparison between the calculated and observed energies is presented in Table B. However, three observed levels, $2s5g(^1G^o)$, $2s6g(^1G^o)$, and $2s6h(^1H^o)$, are missing in the calculated set. A very fine energy mesh of 0.001 Ry used to find the eigenvalues of the Hamiltonian matrix [3] appears not fine enough to obtain these levels. Present calculations

also do not include the highly excited fifteen observed levels of configurations $2p4l$ of the ion.

Comparisons of the gf -, A -values, and lifetimes of C III are made with the available measured values in Table D. Similar to Table C for C II, the transitions are specified as higher level (index k) to lower level (index i), followed by gf - and A -values. The sum of A -values and τ 's are given below the set of transitions. n_k and n_i are the level energy indices for symmetries J_k and J_i , respectively.

The two lowest transitions, $2s^2(^1S_0)-2s2p(^3P_1^o, ^1P_1^o)$, in C III have been studied extensively. Ynnerman and Froese Fisher [36] and Jonsson and Froese Fischer [37] carried out multiconfiguration Dirac–Fock (MCDHF) calculations for the lifetimes of the spin-forbidden $2s^2(^1S_0)-2s2p(^3P_1^o)$ and the spin-allowed $2s^2(^1S_0)-2s2p(^1P_1^o)$ transitions using their modified version of the atomic structure code, GRASP [38]. Berrington et al. [39] calculated the BPRM oscillator strengths for transitions among the levels of the two symmetries, $J = 0^o$ and $J = 1^o$ of configurations $1s^22snl$ and $1s^22pnl$ for n going up to 10. They employed an eigenfunction expansion with 28 fine-structure core levels and correlation orbitals going up to $l \leq 4$. The present BPRM radiative decay rate (A -value) for the intercombination transition $2s^2(^1S_0)-2s2p(^3P_1^o)$ agrees within the uncertainty of the measured value by Kwong et al. [34] and with the result from Berrington et al. [39], while that from Froese Fisher et al. [36, 37] agrees almost exactly with the measured value by Doerfert et al. [35]. Froese Fischer et al. [36, 37] included the Breit interaction in an indirect manner and found the effect to be important for the intercombination transitions. The present oscillator strength f for the dipole allowed transition $2s^2(^1S_0)-2s2p(^1P_1^o)$ agrees quite well with the measured value [29] as well as with other calculations [36, 37, 39, 41, 42].

The BPRM oscillator strength for the dipole allowed transition $1s^22s2p(^1P^o)-1s^22p^2(^1S)$ is close to the measured value [26] and the calculated value [41] while the lifetime of the upper level is within the spread of the measured values. The largest calculations for the C III oscillator strengths were carried out by Tully et al. [43] under the OP. They used a five-state wavefunction expansion of configurations $1s^2nl$, nl going up to $3d$, in contrast to the present expansion which includes higher orbitals up to $4f$. Their nonrelativistic LS lifetime is comparable to the present BPRM value as well as with the measured ones. The present f -value for the $1s^22s2p(^1P^o)-1s^22p^2(^1D)$ transition agrees very well with the measured value [26]. The lifetime of the $2s2p^2(^1D_2)$ level also shows quite good agreement with the measured value by Reistad et al. [26] as well as with the LS lifetime from the OP. For the transition $1s^22s2p(^1P^o)-1s^22s3s(^1S)$, f and τ agree with the measured values within experimental uncertainties. There are disagreements, however, between the present f -values and the earlier BPRM calculations by Berrington et al. [39] for the very weak intercombination transitions. Present BPRM lifetimes for the levels $1s^22s3p(^3P_{0,1,2}^o)$ are compared with the measured value for the LS state and are found to lie within the measured values.

A total of 206 fine structure bound levels of C III are obtained and are available electronically (at [http://www.](http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat)

[idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat](http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat)). The levels are identified spectroscopically and available with effective quantum numbers in two formats, in $J\pi$ order for astrophysical model applications and in LS term order for spectroscopic applications. Sample tables of energies in these two formats are shown in Tables IVa and IVb.

A total of 4202 oscillator strengths (f -values) for fine structure transitions are obtained for C III. The complete table contains gf -values along with the level energies, linestrengths (S) and transition probabilities (A -values). Table V presents a sample of the complete file. These transitions are identified spectroscopically by comparing the energy level indices with those in the energy level Table IVa.

Similar to C II transitions, a part of the oscillator strengths data has been reprocessed for improved accuracy and unique spectroscopic identification for ease of application. The observed transition energies are used with the energy independent linestrength (S) obtained in the BPRM calculations (Eqs. (10) and (11)). The reprocessed set consists of 1884 transitions for C III with spectroscopic notation similar to NIST compilations. These oscillator strengths are ordered in LS multiplets. Statistical averaging for a LS multiplet can be carried out only for the dipole allowed transitions. Sample results are presented in Table VI. The complete table is available electronically (at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>).

SUMMARY AND CONCLUSION

The present work reports on extensive relativistic calculations for C II and C III using the BPRM method. The method entails uniform accuracy for a large set of transition probabilities, since there is no individual term or level optimization; the same wavefunction expansion for each symmetry $J\pi$ is employed representing an extensive configuration interaction.

The Breit interaction can be important for very weak transitions. The BP Hamiltonian (Eq. (2)) in the present BPRM calculations does not include the full Breit-interaction in that the two-body spin–spin and spin–other-orbit terms (Eq. 4) are not included. Detailed comparisons of the present BPRM results with the available measured and other theoretical values show that the effect could be significant for the weak intercombination transitions in C II and in C III. Study of the effect employing the BPRM method as well as atomic structure calculations using SUPERSTRUCTURE are planned.

Electron–electron correlation effects have been studied. It is found that with a larger set of correlation configurations and wavefunction expansion, the energy eigenvalues of C II

show a general improvement over the earlier calculations. However, the transition probabilities and lifetimes of a few levels have relatively poor agreement with the currently available measured values. Results for C III show overall good agreement with other calculations and experiments.

The electronic files are available at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

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EXPLANATION OF TABLES

TABLE Ia. Fine Structure Bound Energy Levels of C II in $J\pi$ Order

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

$C_t SL\pi_t J_t$	Electronic configuration and LS term and total angular momentum of the core (target t)
$n\ell J$	quantum numbers for upper state considered
$E (Ry)$	Level energy (in Rydbergs)
ν	Effective quantum number of the valence electron (no ν for equivalent electron levels)
$SL\pi$	Possible LS terms for the level
Nlv	Total number of levels

TABLE Ib. Fine Structure Bound Energy Levels of C II in LS Term Order

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

Notation is the same as in Table Ia with the following differences:

Nlv	Total number of levels expected followed by the total spin multiplicity and parity, and list of L -values where the corresponding J -values are listed within parentheses
$Nlv(c)$	Total number of calculated levels followed by the information on obtaining complete fine structure set or missing levels

TABLE II. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C II

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

The first two numbers are the nuclear charge and number of core electrons which is followed by sets of transitions for a pair of symmetries.

For each transition set:

Line 1	The four numbers are $2J, \pi, 2J', \pi'$, where parity is 0 for even and 1 for odd
Line 2	Number of energy levels (N and N') of symmetries J and J'
Lines 3 to	Set of transitions: the first two columns are the energy level indices of J and J' , respectively ($N \times N' + 2$)

For a negative gf , J is the lower level, while for a positive gf , J' is the lower level

TABLE III. Transitions in C II in LS Multiplet Order

The table contains a sample of the complete data set which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

Oscillator strengths (f) and radiative decay rates (A) are listed for transitions in C II in LS multiplet order.

TABLE IVa. Fine Structure Bound Energy Levels of C III in $J\pi$ Order

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

Explanations are the same as in Table Ia.

TABLE IVb. Fine Structure Bound Energy Levels of C III in LS Term Order

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

Explanations are the same as in Table Ib.

EXPLANATION OF TABLES continued**TABLE V. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C III**

The table contains a sample of the complete data set, which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>.

Explanations are the same as in Table II.

TABLE VI. Transitions in C III in *LS* Multiplet order

The table contains a sample of the complete data set which is available through the journal website at <http://www.idealibrary.com/links/doi/10.1006/adnd.2002.0879/dat>

Oscillator strengths (f) and radiative decay rates (A) are listed for transitions in C III in *LS* multiplet order

TABLE Ia. Fine Structure Bound Energy Levels of C II in $J\pi$ Order

See page 217 for Explanation of Tables

	C_t	$SL\pi_t$	J_t	nl	J	$E(Ry)$	ν	$SL\pi$
Nlv = 12					$J\pi = 1/2 o$			
1	2s2	1Se	0	2p	1/2	-1.78850E+00	1.21	2 P o
2	2s2	1Se	0	3p	1/2	-5.98472E-01	2.58	2 P o
3	2s2	1Se	0	4p	1/2	-3.10856E-01	3.59	2 P o
4	2s2p	3Po	2	3s	1/2	-2.68252E-01	2.34	4 P o
5	2p3				1/2	-2.32723E-01		2 P o
6	2s2	1Se	0	5p	1/2	-1.84162E-01	4.66	2 P o
7	2s2p	3Po	1	3s	1/2	-1.38873E-01	2.37	2 P o
8	2s2	1Se	0	6p	1/2	-1.22945E-01	5.70	2 P o
9	2s2	1Se	0	7p	1/2	-9.00576E-02	6.66	2 P o
10	2s2	1Se	0	8p	1/2	-6.82044E-02	7.66	2 P o
11	2s2	1Se	0	9p	1/2	-5.33928E-02	8.65	2 P o
12	2s2	1Se	0	10p	1/2	-4.29200E-02	9.65	2 P o
Nlv = 14					$J\pi = 3/2 o$			
1	2s2	1Se	0	2p	3/2	-1.78793E+00	1.33	2 P o
2	2s2	1Se	0	3p	3/2	-5.98368E-01	2.59	2 P o
3	2p3				3/2	-4.61984E-01		4 S o
4	2p3				3/2	-3.91598E-01		2 D o
5	2s2	1Se	0	4p	3/2	-3.10797E-01	3.59	2 P o
6	2s2p	3Po	1	3s	3/2	-2.68006E-01	2.36	4 P o
7	2p3				3/2	-2.32411E-01		2 P o
8	2s2	1Se	0	5p	3/2	-1.84130E-01	4.66	2 P o
9	2s2p	3Po	0	3s	3/2	-1.38783E-01	2.37	2 P o
10	2s2	1Se	0	6p	3/2	-1.22903E-01	5.70	2 P o
11	2s2	1Se	0	7p	3/2	-9.00460E-02	6.66	2 P o
12	2s2	1Se	0	8p	3/2	-6.81980E-02	7.66	2 P o
13	2s2	1Se	0	9p	3/2	-5.33888E-02	8.66	2 P o
14	2s2	1Se	0	10p	3/2	-4.29172E-02	9.65	2 P o
Nlv = 9					$J\pi = 5/2 o$			
1	2p3				5/2	-3.91566E-01		2 D o
2	2s2p	3Po	0	3s	5/2	-2.67594E-01	2.30	4 P o
3	2s2	1Se	0	4f	5/2	-2.52062E-01	3.98	2 F o
4	2s2	1Se	0	5f	5/2	-1.61211E-01	4.98	2 F o
5	2s2	1Se	0	6f	5/2	-1.11862E-01	5.98	2 F o
6	2s2	1Se	0	7f	5/2	-8.21284E-02	6.98	2 F o
7	2s2	1Se	0	8f	5/2	-6.28424E-02	7.98	2 F o
8	2s2	1Se	0	9f	5/2	-4.96284E-02	8.98	2 F o
9	2s2	1Se	0	10f	5/2	-4.01816E-02	9.98	2 F o
Nlv = 7					$J\pi = 7/2 o$			
1	2s2	1Se	0	4f	7/2	-2.52059E-01	3.98	2 F o
2	2s2	1Se	0	5f	7/2	-1.61210E-01	4.98	2 F o
3	2s2	1Se	0	6f	7/2	-1.11862E-01	5.98	2 F o
4	2s2	1Se	0	7f	7/2	-8.21280E-02	6.98	2 F o
5	2s2	1Se	0	8f	7/2	-6.28420E-02	7.98	2 F o
6	2s2	1Se	0	9f	7/2	-4.96280E-02	8.98	2 F o
7	2s2	1Se	0	10f	7/2	-4.01816E-02	9.98	2 F o

TABLE Ia. Fine Structure Bound Energy Levels of C II in $J\pi$ Order
See page 217 for Explanation of Tables

	C_i	$SL\pi_i$	J_i	nl	J	$E(Ry)$	ν	$SL\pi$
Nlv = 5					J π = 9/2 o			
1	2s2	1Se	0	6h	9/2	-1.11164E-01	6.00	2 H o
2	2s2	1Se	0	7h	9/2	-8.16700E-02	7.00	2 H o
3	2s2	1Se	0	8h	9/2	-6.25264E-02	8.00	2 H o
4	2s2	1Se	0	9h	9/2	-4.94020E-02	9.00	2 H o
5	2s2	1Se	0	10h	9/2	-4.00148E-02	10.00	2 H o
Nlv = 5					J π = 11/2 o			
1	2s2	1Se	0	6h	11/2	-1.11164E-01	6.00	2 H o
2	2s2	1Se	0	7h	11/2	-8.16700E-02	7.00	2 H o
3	2s2	1Se	0	8h	11/2	-6.25264E-02	8.00	2 H o
4	2s2	1Se	0	9h	11/2	-4.94020E-02	9.00	2 H o
5	2s2	1Se	0	10h	11/2	-4.00144E-02	10.00	2 H o
Nlv = 3					J π = 13/2 o			
1	2s2	1Se	0	8k	13/2	-6.25012E-02	8.00	2 K o
2	2s2	1Se	0	9k	13/2	-4.93840E-02	9.00	2 K o
3	2s2	1Se	0	10k	13/2	-4.00016E-02	10.00	2 K o

TABLE Ib. Fine Structure Bound Energy Levels of C II in *LS* Term Order

See page 217 for Explanation of Tables

C_I	$S_I L_I \pi_I$	J_I	nl	J	E(cal)	ν	$SL\pi$
Nlv = 2, 2,o: P (3 1)/2							
2s2	(1Se)	0	2p	1	-1.78850E+00	1.21	2 P o
2s2	(1Se)	0	2p	3	-1.78793E+00	1.33	2 P o
Nlv(c) = 2 : set complete							
Eqv electron/unidentified levels, parity: e							
2s2p2				1	-1.39856E+00	0.00	4 P e
2s2p2				3	-1.39835E+00	0.00	4 P e
2s2p2				5	-1.39802E+00	0.00	4 P e
Nlv(c) = 3 : set complete							
Eqv electron/unidentified levels, parity: e							
2s2p2				3	-1.09570E+00	0.00	2 D e
2s2p2				5	-1.09567E+00	0.00	2 D e
Nlv(c) = 2 : set complete							
Eqv electron/unidentified levels, parity: e							
2s2p2				1	-8.77060E-01	0.00	2 S e
Nlv(c) = 1 : set complete							
Eqv electron/unidentified levels, parity: e							
2s2p2				1	-7.55216E-01	0.00	2 P e
2s2p2				3	-7.54808E-01	0.00	2 P e
Nlv(c) = 2 : set complete							
Nlv = 1, 2,e: S (1)/2							
2s2	(1Se)	0	3s	1	-7.26300E-01	2.30	2 S e
Nlv(c) = 1 : set complete							
Nlv = 2, 2,o: P (3 1)/2							
2s2	(1Se)	0	3p	1	-5.98472E-01	2.58	2 P o
2s2	(1Se)	0	3p	3	-5.98368E-01	2.59	2 P o
Nlv(c) = 2 : set complete							
Nlv = 2, 2,e: D (5 3)/2							
2s2	(1Se)	0	3d	3	-4.72180E-01	2.91	2 D e
2s2	(1Se)	0	3d	5	-4.72164E-01	2.91	2 D e
Nlv(c) = 2 : set complete							
Eqv electron/unidentified levels, parity: o							
2p3				3	-4.61984E-01	0.00	4 S o
Nlv(c) = 1 : set complete							
Eqv electron/unidentified levels, parity: o							
2p3				3	-3.91598E-01	0.00	2 D o
2p3				5	-3.91566E-01	0.00	2 D o
Nlv(c) = 2 : set complete							
Nlv = 1, 2,e: S (1)/2							
2s2	(1Se)	0	4s	1	-3.59400E-01	3.34	2 S e
Nlv(c) = 1 : set complete							

TABLE Ib. Fine Structure Bound Energy Levels of C II in *LS* Term Order

See page 217 for Explanation of Tables

C_I	$S_I L_I \pi_I$	J_I	nl	J	E(cal)	ν	$SL\pi$
Nlv = 2, 2,o: P (3 1)/2							
2s2	(1Se)	0	4p	1	-3.10856E-01	3.59	2 P o
2s2	(1Se)	0	4p	3	-3.10797E-01	3.59	2 P o
Nlv(c) = 2 : set complete							
Nlv = 3, 4,o: P (5 3 1)/2							
2s2p	(3Po)	2	3s	1	-2.68252E-01	2.34	4 P o
2s2p	(3Po)	1	3s	3	-2.68006E-01	2.36	4 P o
2s2p	(3Po)	0	3s	5	-2.67594E-01	2.30	4 P o
Nlv(c) = 3 : set complete							
Nlv = 2, 2,e: D (5 3)/2							
2s2	(1Se)	0	4d	3	-2.60052E-01	3.92	2 D e
2s2	(1Se)	0	4d	5	-2.60043E-01	3.92	2 D e
Nlv(c) = 2 : set complete							
Nlv = 2, 2,o: F (7 5)/2							
2s2	(1Se)	0	4f	5	-2.52062E-01	3.98	2 F o
2s2	(1Se)	0	4f	7	-2.52059E-01	3.98	2 F o
Nlv(c) = 2 : set complete							

TABLE II. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C II
 See page 217 for Explanation of Tables

12	6	5			$E_j(\text{Ry})$	gf_L	S	$A_{ji}(\text{sec}^{-1})$
	1	1	1	0				
1	14	$E_i(\text{Ry})$						
1	1	-1.78850E+00			-1.39855E+00	-8.483E-08	6.526E-07	5.181E+01
1	2	-1.78850E+00			-8.77060E-01	-2.758E-01	9.078E-01	9.202E+08
1	3	-1.78850E+00			-7.55216E-01	-6.868E-01	1.994E+00	2.945E+09
1	4	-1.78850E+00			-7.26301E-01	-1.189E-02	3.358E-02	5.386E+07
1	5	-1.78850E+00			-3.59400E-01	-1.126E-02	2.364E-02	9.238E+07
1	6	-1.78850E+00			-2.12253E-01	-4.350E-03	8.279E-03	4.340E+07
1	7	-1.78850E+00			-1.40140E-01	-2.061E-03	3.751E-03	2.249E+07
1	8	-1.78850E+00			-1.32820E-01	-2.623E-05	4.753E-05	2.887E+05
1	9	-1.78850E+00			-1.27264E-01	-2.302E-02	4.157E-02	2.552E+08
1	10	-1.78850E+00			-9.94665E-02	-1.131E-03	2.009E-03	1.296E+07
1	11	-1.78850E+00			-8.84214E-02	-2.280E-07	4.023E-07	2.647E+03
1	12	-1.78850E+00			-7.42736E-02	-6.524E-04	1.142E-03	7.700E+06
1	13	-1.78850E+00			-5.75932E-02	-3.817E-04	6.616E-04	4.593E+06
1	14	-1.78850E+00			-4.59874E-02	-2.131E-04	3.669E-04	2.598E+06
2	1	-5.98470E-01			-1.39855E+00	1.581E-08	5.928E-08	4.064E+01
2	2	-5.98470E-01			-8.77060E-01	1.413E-01	1.522E+00	4.405E+07
2	3	-5.98470E-01			-7.55216E-01	5.450E-04	1.043E-02	5.378E+04
2	4	-5.98470E-01			-7.26301E-01	4.090E-01	9.599E+00	2.684E+07
2	5	-5.98470E-01			-3.59400E-01	-2.902E-01	3.642E+00	6.661E+07
2	6	-5.98470E-01			-2.12253E-01	-4.481E-02	3.481E-01	2.684E+07
2	7	-5.98470E-01			-1.40140E-01	-1.604E-02	1.050E-01	1.354E+07
2	8	-5.98470E-01			-1.32820E-01	-1.756E-05	1.131E-04	1.529E+04
2	9	-5.98470E-01			-1.27264E-01	-1.481E-02	9.429E-02	1.320E+07
2	10	-5.98470E-01			-9.94665E-02	-7.745E-03	4.656E-02	7.746E+06
2	11	-5.98470E-01			-8.84214E-02	-1.174E-07	6.905E-07	1.226E+02
2	12	-5.98470E-01			-7.42736E-02	-4.263E-03	2.440E-02	4.705E+06
2	13	-5.98470E-01			-5.75932E-02	-2.500E-03	1.387E-02	2.937E+06
2	14	-5.98470E-01			-4.59874E-02	-1.478E-03	8.026E-03	1.812E+06
3	1	-3.10856E-01			-1.39855E+00	2.190E-08	6.040E-08	1.041E+02
3	2	-3.10856E-01			-8.77060E-01	9.503E-04	5.035E-03	1.224E+06
3	3	-3.10856E-01			-7.55216E-01	7.266E-03	4.905E-02	5.762E+06
3	4	-3.10856E-01			-7.26301E-01	3.210E-02	2.318E-01	2.225E+07
3	5	-3.10856E-01			-3.59400E-01	7.313E-01	4.519E+01	6.920E+06
3	6	-3.10856E-01			-2.12253E-01	-3.978E-01	1.210E+01	1.553E+07
3	7	-3.10856E-01			-1.40140E-01	-5.895E-02	1.036E+00	6.900E+06
3	8	-3.10856E-01			-1.32820E-01	-3.357E-05	5.657E-04	4.273E+03
3	9	-3.10856E-01			-1.27264E-01	-2.504E-02	4.092E-01	3.390E+06
3	10	-3.10856E-01			-9.94665E-02	-2.073E-02	2.942E-01	3.720E+06
3	11	-3.10856E-01			-8.84214E-02	-1.104E-06	1.489E-05	2.193E+02
3	12	-3.10856E-01			-7.42736E-02	-9.632E-03	1.221E-01	2.165E+06
3	13	-3.10856E-01			-5.75932E-02	-5.029E-03	5.957E-02	1.296E+06
3	14	-3.10856E-01			-4.59874E-02	-2.684E-03	3.040E-02	7.561E+05
4	1	-2.68252E-01			-1.39855E+00	4.508E-02	1.196E-01	2.313E+08
4	2	-2.68252E-01			-8.77060E-01	2.196E-07	1.082E-06	3.269E+02
4	3	-2.68252E-01			-7.55216E-01	3.682E-07	2.268E-06	3.507E+02
4	4	-2.68252E-01			-7.26301E-01	2.749E-08	1.800E-07	2.317E+01
4	5	-2.68252E-01			-3.59400E-01	3.282E-06	1.080E-04	1.095E+02
4	6	-2.68252E-01			-2.12253E-01	-2.781E-06	1.490E-04	3.503E+01
4	7	-2.68252E-01			-1.40140E-01	-3.055E-07	7.154E-06	2.014E+01
4	8	-2.68252E-01			-1.32820E-01	-4.190E-01	9.281E+00	3.086E+07
4	9	-2.68252E-01			-1.27264E-01	-4.426E-04	9.418E-03	3.533E+04

TABLE II. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C II
 See page 217 for Explanation of Tables

4	10	-2.68252E-01	-9.94665E-02	-5.753E-07	1.023E-05	6.583E+01
4	11	-2.68252E-01	-8.84214E-02	-1.198E-01	1.999E+00	1.556E+07
4	12	-2.68252E-01	-7.42736E-02	-3.530E-08	5.459E-07	5.335E+00
4	13	-2.68252E-01	-5.75932E-02	-6.382E-11	9.089E-10	1.137E-02
4	14	-2.68252E-01	-4.59874E-02	-6.460E-10	8.719E-09	1.282E-01
5	1	-2.32723E-01	-1.39855E+00	3.083E-07	7.933E-07	1.683E+03
5	2	-2.32723E-01	-8.77060E-01	1.670E-02	7.775E-02	2.785E+07
5	3	-2.32723E-01	-7.55216E-01	1.406E-01	8.073E-01	1.542E+08
5	4	-2.32723E-01	-7.26301E-01	3.211E-03	1.952E-02	3.141E+06
5	5	-2.32723E-01	-3.59400E-01	1.195E-01	2.830E+00	7.703E+06
5	6	-2.32723E-01	-2.12253E-01	-1.167E-01	1.710E+01	1.964E+05
5	7	-2.32723E-01	-1.40140E-01	-9.266E-06	3.003E-04	3.190E+02
5	8	-2.32723E-01	-1.32820E-01	-1.054E-04	3.165E-03	4.223E+03
5	9	-2.32723E-01	-1.27264E-01	-1.348E-01	3.835E+00	6.020E+06
5	10	-2.32723E-01	-9.94665E-02	-6.398E-05	1.440E-03	4.563E+03
5	11	-2.32723E-01	-8.84214E-02	-5.265E-07	1.095E-05	4.403E+01
5	12	-2.32723E-01	-7.42736E-02	-2.968E-04	5.619E-03	2.993E+04
5	13	-2.32723E-01	-5.75932E-02	-6.759E-04	1.158E-02	8.326E+04
5	14	-2.32723E-01	-4.59874E-02	-1.322E-03	2.124E-02	1.851E+05

TABLE III. Transitions in C II in LS Multiplet Order
See page 217 for Explanation of Tables

$Conf_i$	$Conf_k$	LS_i	LS_k	$2J_i : n_i$	$2J_k : n_k$	$\lambda(\text{\AA})$	f_{ik}	$A_{ki}(s^{-1})$
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$4P^e$	2:1	2:1	2328.4	4.261E-08	5.25E+01
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$4P^e$	2:1	4:1	2327.2	1.936E-09	1.19E+00
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$4P^e$	4:1	2:1	2331.4	2.192E-08	5.39E+01
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$4P^e$	4:1	4:1	2330.2	9.236E-09	1.14E+01
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$4P^e$	4:1	6:1	2328.4	4.179E-08	3.44E+01
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2S^e$	2:1	2:2	1037.5	1.330E-01	8.26E+08
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2S^e$	4:1	2:2	1038.1	1.314E-01	1.63E+09
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2S^e$	6:0	2:0	1037.8	1.319E-01	2.46E+09
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2P^e$	2:1	2:3	905.0	3.350E-01	2.73E+09
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2P^e$	2:1	4:3	904.7	1.681E-01	6.86E+08
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2P^e$	4:1	2:3	905.5	8.489E-02	1.38E+09
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2P^e$	4:1	4:3	905.1	4.207E-01	3.43E+09
$2s2(1S)2p$	$-2s2p2$	$2P^o$	$2P^e$	6:0	6:0	905.0	5.048E-01	4.12E+09
$2s2(1S)2p$	$-2s2(1S)3s$	$2P^o$	$2S^e$	2:1	2:4	859.1	5.943E-03	5.38E+07
$2s2(1S)2p$	$-2s2(1S)3s$	$2P^o$	$2S^e$	4:1	2:4	859.5	5.454E-03	9.87E+07
$2s2(1S)2p$	$-2s2(1S)3s$	$2P^o$	$2S^e$	6:0	2:0	859.3	5.617E-03	1.53E+08
$2s2(1S)2p$	$-2s2(1S)4s$	$2P^o$	$2S^e$	2:1	2:5	636.7	5.645E-03	9.31E+07
$2s2(1S)2p$	$-2s2(1S)4s$	$2P^o$	$2S^e$	4:1	2:5	636.9	5.662E-03	1.87E+08
$2s2(1S)2p$	$-2s2(1S)4s$	$2P^o$	$2S^e$	6:0	2:0	636.8	5.656E-03	2.80E+08
$2s2(1S)2p$	$-2s2(1S)5s$	$2P^o$	$2S^e$	2:1	2:6	577.5	2.180E-03	4.37E+07
$2s2(1S)2p$	$-2s2(1S)5s$	$2P^o$	$2S^e$	4:1	2:6	577.7	2.186E-03	8.76E+07
$2s2(1S)2p$	$-2s2(1S)5s$	$2P^o$	$2S^e$	6:0	2:0	577.6	2.184E-03	1.31E+08
$2s2(1S)2p$	$-2s2(1S)6s$	$2P^o$	$2S^e$	2:1	2:7	552.3	1.033E-03	2.26E+07
$2s2(1S)2p$	$-2s2(1S)6s$	$2P^o$	$2S^e$	4:1	2:7	552.5	1.043E-03	4.57E+07
$2s2(1S)2p$	$-2s2(1S)6s$	$2P^o$	$2S^e$	6:0	2:0	552.4	1.040E-03	6.83E+07

TABLE III. Transitions in C II in LS Multiplet Order
See page 217 for Explanation of Tables

$Conf_i$	$Conf_k$	LS_i	LS_k	$2J_i : n_i$	$2J_k : n_k$	$\lambda(\text{\AA})$	f_{ik}	$A_{ki}(s^{-1})$
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4D^e$	2:1	2:8	551.0	1.312E-05	2.89E+05
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4D^e$	2:1	4:7	551.0	2.343E-06	2.58E+04
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4D^e$	4:1	2:8	551.2	3.237E-06	1.42E+05
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4D^e$	4:1	4:7	551.1	8.537E-06	1.88E+05
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4D^e$	4:1	6:6	551.0	1.103E-07	1.62E+03
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$2P^e$	2:1	2:9	550.0	1.149E-02	2.54E+08
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$2P^e$	2:1	4:8	549.9	5.870E-03	6.49E+07
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$2P^e$	4:1	2:9	550.2	2.848E-03	1.26E+08
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$2P^e$	4:1	4:8	550.1	1.428E-02	3.15E+08
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$2P^e$	6:0	6:0	550.1	1.721E-02	3.80E+08
$2s2(1S)2p$	$-2s2(1S)7s$	$2P^o$	$2S^e$	2:1	2:10	539.0	5.667E-04	1.30E+07
$2s2(1S)2p$	$-2s2(1S)7s$	$2P^o$	$2S^e$	4:1	2:10	539.2	5.644E-04	2.60E+07
$2s2(1S)2p$	$-2s2(1S)7s$	$2P^o$	$2S^e$	6:0	2:0	539.1	5.652E-04	3.90E+07
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4P^e$	2:1	2:11	537.0	1.139E-07	2.64E+03
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4P^e$	2:1	4:11	536.9	2.694E-07	3.12E+03
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4P^e$	4:1	2:11	537.2	6.918E-10	3.21E+01
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4P^e$	4:1	4:11	537.1	3.608E-07	8.36E+03
$2s2(1S)2p$	$-2s2p(3Po)3p$	$2P^o$	$4P^e$	4:1	6:8	537.0	3.302E-06	5.10E+04
$2s2p2$	$-2s2(1S)3p$	$4P^e$	$2P^o$	2:1	2:2	1128.3	7.988E-09	4.19E+01
$2s2p2$	$-2s2(1S)3p$	$4P^e$	$2P^o$	4:1	2:2	1128.6	2.197E-09	2.31E+01
$2s2p2$	$-2s2(1S)3p$	$4P^e$	$2P^o$	2:1	4:2	1128.2	2.182E-08	5.73E+01
$2s2p2$	$-2s2(1S)3p$	$4P^e$	$2P^o$	4:1	4:2	1128.5	1.750E-09	9.18E+00
$2s2p2$	$-2s2(1S)3p$	$4P^e$	$2P^o$	6:1	4:2	1128.9	2.261E-08	1.78E+02
$2s2p2$	$-2s2(1S)3p$	$2S^e$	$2P^o$	2:2	2:2	2842.0	8.144E-02	6.74E+07
$2s2p2$	$-2s2(1S)3p$	$2S^e$	$2P^o$	2:2	4:2	2841.1	1.630E-01	6.75E+07
$2s2p2$	$-2s2(1S)3p$	$2S^e$	$2P^o$	2:0	6:0	2841.1	2.444E-01	6.75E+07

TABLE IVa. Fine Structure Bound Energy Levels of C III in $J\pi$ Order

See page 217 for Explanation of Tables

	C_I	$SL\pi_I$	J_I	nl	J	$E(Ry)$	ν	$SL\pi$
Nlv = 15					$J\pi = 0 e$			
1	1s22s2				0	-3.51280E+00		1 S e
2	1s22p2				0	-2.24475E+00		3 P e
3	1s22p2				0	-1.80983E+00		1 S e
4	1s22s	2Se	1/2	3s	0	-1.26290E+00	2.67	1 S e
5	1s22s	2Se	1/2	4s	0	-6.77594E-01	3.64	1 S e
6	1s22p	2Po	3/2	3p	0	-5.03450E-01	2.87	3 P e
7	1s22s	2Se	1/2	5s	0	-4.30715E-01	4.57	1 S e
8	1s22p	2Po	1/2	3p	0	-3.61484E-01	2.87	1 S e
9	1s22s	2Se	1/2	6s	0	-2.76882E-01	5.70	1 S e
10	1s22s	2Se	1/2	7s	0	-2.02148E-01	6.67	1 S e
11	1s22s	2Se	1/2	8s	0	-1.53335E-01	7.66	1 S e
12	1s22s	2Se	1/2	9s	0	-1.20164E-01	8.65	1 S e
13	1s22s	2Se	1/2	10s	0	-9.66645E-02	9.65	1 S e
14	1s22p	2Po	1/2	4p	0	-9.39654E-02	3.62	3 P e
15	1s22p	2Po	1/2	4p	0	-9.39618E-02	3.62	1 S e
Nlv = 11					$J\pi = 0 o$			
1	1s22s	2Se	1/2	2p	0	-3.03287E+00	1.72	3 P o
2	1s22s	2Se	1/2	3p	0	-1.14956E+00	2.80	3 P o
3	1s22p	2Po	3/2	3s	0	-7.02829E-01	2.64	3 P o
4	1s22s	2Se	1/2	4p	0	-6.21712E-01	3.80	3 P o
5	1s22p	2Po	3/2	3d	0	-4.12842E-01	2.90	3 P o
6	1s22s	2Se	1/2	5p	0	-3.80254E-01	4.86	3 P o
7	1s22s	2Se	1/2	6p	0	-2.65416E-01	5.82	3 P o
8	1s22s	2Se	1/2	7p	0	-1.93579E-01	6.82	3 P o
9	1s22s	2Se	1/2	8p	0	-1.47326E-01	7.82	3 P o
10	1s22s	2Se	1/2	9p	0	-1.15859E-01	8.81	3 P o
11	1s22s	2Se	1/2	10p	0	-9.35370E-02	9.81	3 P o

TABLE IVa. Fine Structure Bound Energy Levels of C III in $J\pi$ Order

See page 217 for Explanation of Tables

	C_t	$SL\pi_t$	J_t	nl	J	$E(Ry)$	ν	$SL\pi$
Nlv = 21					$J\pi = 1e$			
1	1s22p2				1	-2.24450E+00		3 P e
2	1s22s	2Se	1/2	3s	1	-1.34654E+00	2.58	3 S e
3	1s22s	2Se	1/2	3d	1	-1.05745E+00	2.92	3 D e
4	1s22s	2Se	1/2	4s	1	-6.98030E-01	3.59	3 S e
5	1s22p	2Po	1/2	3p	1	-5.96913E-01	2.75	1 P e
6	1s22s	2Se	1/2	4d	1	-5.87502E-01	3.91	3 D e
7	1s22p	2Po	3/2	3p	1	-5.68231E-01	2.79	3 SPD e
8	1s22p	2Po	1/2	3p	1	-5.28052E-01	2.84	3 SPD e
9	1s22p	2Po	3/2	3p	1	-5.03269E-01	2.87	3 SPD e
10	1s22s	2Se	1/2	5s	1	-4.21391E-01	4.62	3 S e
11	1s22s	2Se	1/2	5d	1	-3.71122E-01	4.92	3 D e
12	1s22s	2Se	1/2	6s	1	-2.85651E-01	5.61	3 S e
13	1s22s	2Se	1/2	6d	1	-2.56175E-01	5.93	3 D e
14	1s22s	2Se	1/2	7s	1	-2.06018E-01	6.61	3 S e
15	1s22s	2Se	1/2	7d	1	-1.87590E-01	6.93	3 D e
16	1s22s	2Se	1/2	8s	1	-1.55539E-01	7.61	3 S e
17	1s22s	2Se	1/2	8d	1	-1.43264E-01	7.93	3 D e
18	1s22s	2Se	1/2	9s	1	-1.21569E-01	8.60	3 S e
19	1s22s	2Se	1/2	9d	1	-1.12970E-01	8.93	3 D e
20	1s22s	2Se	1/2	10s	1	-9.76302E-02	9.60	3 S e
21	1s22s	2Se	1/2	10d	1	-9.13572E-02	9.92	3 D e
Nlv = 23					$J\pi = 1o$			
1	1s22s	2Se	1/2	2p	1	-3.03261E+00	1.72	3 P o
2	1s22s	2Se	1/2	2p	1	-2.56307E+00	1.87	1 P o
3	1s22s	2Se	1/2	3p	1	-1.15559E+00	2.79	1 P o
4	1s22s	2Se	1/2	3p	1	-1.14950E+00	2.80	3 P o
5	1s22p	2Po	3/2	3s	1	-7.02542E-01	2.64	3 P o
6	1s22p	2Po	3/2	3s	1	-6.88638E-01	2.61	1 P o
7	1s22s	2Se	1/2	4p	1	-6.21691E-01	3.80	3 P o
8	1s22s	2Se	1/2	4p	1	-5.75301E-01	3.80	1 P o
9	1s22p	2Po	3/2	3d	1	-4.34448E-01	2.97	3 PD o
10	1s22p	2Po	3/2	3d	1	-4.12933E-01	2.97	3 PD o
11	1s22s	2Se	1/2	5p	1	-3.88769E-01	4.81	1 P o
12	1s22s	2Se	1/2	5p	1	-3.80278E-01	4.86	3 P o
13	1s22p	2Po	3/2	3d	1	-3.50844E-01	2.97	1 P o
14	1s22s	2Se	1/2	6p	1	-2.65411E-01	5.82	3 P o
15	1s22s	2Se	1/2	6p	1	-2.64672E-01	5.83	1 P o
16	1s22s	2Se	1/2	7p	1	-1.94090E-01	6.81	1 P o
17	1s22s	2Se	1/2	7p	1	-1.93576E-01	6.82	3 P o
18	1s22s	2Se	1/2	8p	1	-1.48334E-01	7.79	1 P o
19	1s22s	2Se	1/2	8p	1	-1.47324E-01	7.82	3 P o
20	1s22s	2Se	1/2	9p	1	-1.17221E-01	8.76	1 P o
21	1s22s	2Se	1/2	9p	1	-1.15856E-01	8.81	3 P o
22	1s22s	2Se	1/2	10p	1	-9.53127E-02	9.72	1 P o
23	1s22s	2Se	1/2	10p	1	-9.35325E-02	9.81	3 P o

TABLE IVb. Fine Structure Bound Energy Levels of C III in *LS* Term Order

See page 217 for Explanation of Tables

C_I	$S_I L_I \pi_I$	J_I	nl	J	E (cal)	ν	$SL\pi$
Eqv electron/unidentified levels, parity : e							
1s22s2				0	-3.51280E+00		1 S e
Nlv(c) = 1 : set complete							
Nlv = 3, 3,o: P (2 1 0)							
1s22s	(2Se)	1/2	2p	0	-3.03287E+00	1.72	3 P o
1s22s	(2Se)	1/2	2p	1	-3.03261E+00	1.72	3 P o
1s22s	(2Se)	1/2	2p	2	-3.03211E+00	1.72	3 P o
Nlv(c) = 3 : set complete							
Nlv = 1, 1,o: P (1)							
1s22s	(2Se)	1/2	2p	1	-2.56307E+00	1.87	1 P o
Nlv(c) = 1 : set complete							
Eqv electron/unidentified levels, parity : e							
1s22p2				0	-1.80983E+00		1 S e
Nlv(c) = 1 : set complete							
Nlv = 1, 3,e: S (1)							
1s22s	(2Se)	1/2	3s	1	-1.34654E+00	2.58	3 S e
Nlv(c) = 1 : set complete							
Nlv = 1, 1,e: S (0)							
1s22s	(2Se)	1/2	3s	0	-1.26290E+00	2.67	1 S e
Nlv(c) = 1 : set complete							
Nlv = 1, 1,o: P (1)							
1s22s	(2Se)	1/2	3p	1	-1.15559E+00	2.79	1 P o
Nlv(c) = 1 : set complete							
Nlv = 3, 3,o: P (2 1 0)							
1s22s	(2Se)	1/2	3p	0	-1.14956E+00	2.80	3 P o
1s22s	(2Se)	1/2	3p	1	-1.14950E+00	2.80	3 P o
1s22s	(2Se)	1/2	3p	2	-1.14939E+00	2.80	3 P o
Nlv(c) = 3 : set complete							
Nlv = 3, 3,e: D (3 2 1)							
1s22s	(2Se)	1/2	3d	1	-1.05745E+00	2.92	3 D e
1s22s	(2Se)	1/2	3d	2	-1.05743E+00	2.92	3 D e
1s22s	(2Se)	1/2	3d	3	-1.05739E+00	2.92	3 D e
Nlv(c) = 3 : set complete							

TABLE IVb. Fine Structure Bound Energy Levels of C III in *LS* Term Order

See page 217 for Explanation of Tables

C_i	$S_i L_i \pi_i$	J_i	nl	J	E (cal)	ν	$SL\pi$
Nlv = 1, 1,e: D (2)							
1s22s	(2Se)	1/2	3d	2	-9.95940E-01	3.01	1 D e
Nlv(c) = 1 : set complete							
Nlv = 3, 3,o: P (2 1 0)							
1s22p	(2Po)	3/2	3s	0	-7.02829E-01	2.64	3 P o
1s22p	(2Po)	3/2	3s	1	-7.02542E-01	2.64	3 P o
1s22p	(2Po)	1/2	3s	2	-7.01944E-01	2.64	3 P o
Nlv(c) = 3 : set complete							
Nlv = 1, 3,e: S (1)							
1s22s	(2Se)	1/2	4s	1	-6.98030E-01	3.59	3 S e
Nlv(c) = 1 : set complete							
Nlv = 1, 1,o: P (1)							
1s22p	(2Po)	3/2	3s	1	-6.88638E-01	2.61	1 P o
Nlv(c) = 1 : set complete							
Nlv = 1, 1,e: S (0)							
1s22s	(2Se)	1/2	4s	0	-6.77594E-01	3.64	1 S e
Nlv(c) = 1 : set complete							
Nlv = 3, 3,o: P (2 1 0)							
1s22s	(2Se)	1/2	4p	0	-6.21712E-01	3.80	3 P o
1s22s	(2Se)	1/2	4p	1	-6.21691E-01	3.80	3 P o
1s22s	(2Se)	1/2	4p	2	-6.21650E-01	3.80	3 P o
Nlv(c) = 3 : set complete							

TABLE V. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C III
 See page 218 for Explanation of Tables

15	6	4			$E_j(Ry)$	gfL	S	$A_{ji}(sec^{-1})$
	0	0	2	1				
	23	$E_i(Ry)$						
1	1	-3.51280E+00			-3.03261E+00	-2.059E-07	1.286E-06	1.271E+02
1	2	-3.51280E+00			-2.56307E+00	-7.812E-01	2.468E+00	1.886E+09
1	3	-3.51280E+00			-1.15559E+00	-2.312E-01	2.942E-01	3.439E+09
1	4	-3.51280E+00			-1.14950E+00	-1.021E-04	1.296E-04	1.528E+06
1	5	-3.51280E+00			-7.02542E-01	-1.966E-05	2.099E-05	4.157E+05
1	6	-3.51280E+00			-6.88638E-01	-4.506E-02	4.787E-02	9.623E+08
1	7	-3.51280E+00			-6.21691E-01	-1.949E-07	2.022E-07	4.361E+03
1	8	-3.51280E+00			-5.75301E-01	-2.806E-02	2.866E-02	6.484E+08
1	9	-3.51280E+00			-4.34448E-01	-7.383E-07	7.195E-07	1.873E+04
1	10	-3.51280E+00			-4.12933E-01	-5.762E-07	5.576E-07	1.482E+04
1	11	-3.51280E+00			-3.88768E-01	-4.473E-02	4.295E-02	1.169E+09
1	12	-3.51280E+00			-3.80278E-01	-3.141E-07	3.008E-07	8.252E+03
1	13	-3.51280E+00			-3.50844E-01	-3.280E-03	3.112E-03	8.781E+07
1	14	-3.51280E+00			-2.65411E-01	-6.724E-10	6.212E-10	1.898E+01
1	15	-3.51280E+00			-2.64672E-01	-1.646E-02	1.520E-02	4.651E+08
1	16	-3.51280E+00			-1.94089E-01	-1.140E-02	1.031E-02	3.362E+08
1	17	-3.51280E+00			-1.93575E-01	-3.127E-07	2.826E-07	9.225E+03
1	18	-3.51280E+00			-1.48335E-01	-7.810E-03	6.964E-03	2.367E+08
1	19	-3.51280E+00			-1.47324E-01	-7.976E-08	7.110E-08	2.419E+03
1	20	-3.51280E+00			-1.17221E-01	-5.498E-03	4.857E-03	1.697E+08
1	21	-3.51280E+00			-1.15856E-01	-5.192E-08	4.585E-08	1.604E+03
1	22	-3.51280E+00			-9.53124E-02	-3.860E-03	3.388E-03	1.207E+08
1	23	-3.51280E+00			-9.35329E-02	-1.220E-07	1.070E-07	3.818E+03
2	1	-2.24475E+00			-3.03261E+00	2.812E-01	1.071E+00	1.402E+09
2	2	-2.24475E+00			-2.56307E+00	2.114E-07	1.992E-06	1.720E+02
2	3	-2.24475E+00			-1.15559E+00	-1.237E-08	3.407E-08	3.930E+01
2	4	-2.24475E+00			-1.14950E+00	-1.803E-04	4.939E-04	5.790E+05
2	5	-2.24475E+00			-7.02542E-01	-1.323E-01	2.574E-01	8.423E+08
2	6	-2.24475E+00			-6.88638E-01	-6.246E-05	1.204E-04	4.050E+05
2	7	-2.24475E+00			-6.21691E-01	-3.771E-03	6.970E-03	2.660E+07
2	8	-2.24475E+00			-5.75301E-01	-1.191E-07	2.140E-07	8.889E+02
2	9	-2.24475E+00			-4.34448E-01	-7.424E-01	1.230E+00	6.514E+09
2	10	-2.24475E+00			-4.12933E-01	-1.619E-01	2.651E-01	1.455E+09
2	11	-2.24475E+00			-3.88768E-01	-5.893E-06	9.525E-06	5.435E+04
2	12	-2.24475E+00			-3.80278E-01	-5.525E-02	8.890E-02	5.143E+08
2	13	-2.24475E+00			-3.50844E-01	-2.047E-05	3.242E-05	1.966E+05
2	14	-2.24475E+00			-2.65411E-01	-8.858E-04	1.343E-03	9.292E+06
2	15	-2.24475E+00			-2.64672E-01	-2.972E-08	4.503E-08	3.120E+02
2	16	-2.24475E+00			-1.94089E-01	-3.063E-08	4.481E-08	3.449E+02
2	17	-2.24475E+00			-1.93575E-01	-1.472E-04	2.153E-04	1.658E+06

TABLE V. Oscillator Strengths, Line Strengths, and Transition Probabilities for Fine Structure Transitions in C III
See page 218 for Explanation of Tables

2	18	-2.24475E+00	-1.48335E-01	-3.883E-08	5.557E-08	4.570E+02
2	19	-2.24475E+00	-1.47324E-01	-4.225E-05	6.043E-05	4.976E+05
2	20	-2.24475E+00	-1.17221E-01	-1.304E-07	1.839E-07	1.581E+03
2	21	-2.24475E+00	-1.15856E-01	-2.632E-05	3.709E-05	3.194E+05
2	22	-2.24475E+00	-9.53124E-02	-1.274E-06	1.778E-06	1.576E+04
2	23	-2.24475E+00	-9.35329E-02	-1.355E-04	1.890E-04	1.678E+06
3	1	-1.80983E+00	-3.03261E+00	8.712E-08	2.137E-07	1.046E+03
3	2	-1.80983E+00	-2.56307E+00	5.169E-01	2.059E+00	2.355E+09
3	3	-1.80983E+00	-1.15559E+00	-2.265E-02	1.039E-01	2.596E+07
3	4	-1.80983E+00	-1.14950E+00	-9.983E-06	4.535E-05	1.165E+04
3	5	-1.80983E+00	-7.02542E-01	-7.290E-05	1.975E-04	2.393E+05
3	6	-1.80983E+00	-6.88638E-01	-1.373E-01	3.674E-01	4.620E+08
3	7	-1.80983E+00	-6.21691E-01	-1.139E-06	2.876E-06	4.305E+03
3	8	-1.80983E+00	-5.75301E-01	-6.679E-02	1.623E-01	2.725E+08
3	9	-1.80983E+00	-4.34448E-01	-1.195E-05	2.607E-05	6.050E+04
3	10	-1.80983E+00	-4.12933E-01	-8.233E-06	1.768E-05	4.301E+04
3	11	-1.80983E+00	-3.88768E-01	-7.068E-02	1.492E-01	3.821E+08
3	12	-1.80983E+00	-3.80278E-01	-4.261E-06	8.942E-06	2.331E+04
3	13	-1.80983E+00	-3.50844E-01	-8.352E-01	1.717E+00	4.760E+09
3	14	-1.80983E+00	-2.65411E-01	-5.615E-08	1.091E-07	3.586E+02
3	15	-1.80983E+00	-2.64672E-01	-1.325E-02	2.573E-02	8.471E+07
3	16	-1.80983E+00	-1.94089E-01	-1.371E-03	2.546E-03	9.585E+06
3	17	-1.80983E+00	-1.93575E-01	-1.261E-08	2.341E-08	8.818E+01
3	18	-1.80983E+00	-1.48335E-01	-3.660E-05	6.609E-05	2.705E+05
3	19	-1.80983E+00	-1.47324E-01	-2.023E-10	3.651E-10	1.497E+00
3	20	-1.80983E+00	-1.17221E-01	-2.345E-04	4.156E-04	1.799E+06
3	21	-1.80983E+00	-1.15856E-01	-1.379E-09	2.442E-09	1.059E+01
3	22	-1.80983E+00	-9.53124E-02	-1.383E-03	2.420E-03	1.088E+07
3	23	-1.80983E+00	-9.35329E-02	-2.088E-09	3.650E-09	1.647E+01
4	1	-1.26290E+00	-3.03261E+00	2.674E-10	4.533E-10	6.727E+00
4	2	-1.26290E+00	-2.56307E+00	5.585E-02	1.289E-01	7.583E+08
4	3	-1.26290E+00	-1.15559E+00	-3.294E-01	9.209E+00	1.015E+07
4	4	-1.26290E+00	-1.14950E+00	-1.618E-04	4.281E-03	5.569E+03
4	5	-1.26290E+00	-7.02542E-01	-3.694E-04	1.978E-03	3.106E+05
4	6	-1.26290E+00	-6.88638E-01	-6.843E-01	3.575E+00	6.042E+08
4	7	-1.26290E+00	-6.21691E-01	-5.525E-07	2.585E-06	6.081E+02
4	8	-1.26290E+00	-5.75301E-01	-2.715E-02	1.185E-01	3.436E+07
4	9	-1.26290E+00	-4.34448E-01	-7.313E-07	2.648E-06	1.344E+03
4	10	-1.26290E+00	-4.12933E-01	-1.401E-07	4.945E-07	2.710E+02
4	11	-1.26290E+00	-3.88768E-01	-3.581E-03	1.229E-02	7.326E+06
4	12	-1.26290E+00	-3.80278E-01	-1.236E-06	4.201E-06	2.578E+03
4	13	-1.26290E+00	-3.50844E-01	-5.302E-02	1.744E-01	1.181E+08
4	14	-1.26290E+00	-2.65411E-01	-1.533E-11	4.611E-11	4.084E-02
4	15	-1.26290E+00	-2.64672E-01	-1.925E-02	5.785E-02	5.134E+07

TABLE VI. Transitions in C III in *LS* Multiplet Order
See page 218 for Explanation of Tables

$Conf_i$	$Conf_k$	LS_i	LS_k	$g_i : n_i$	$g_k : n_k$	$\lambda(\text{\AA})$	f_{ik}	$A_{ki}(s^{-1})$
2s2	-2s2p	$^1S^e$	$^3P^o$	1:1	3:1	1910.9	2.046E-07	1.25E+02
2s2	-2s2p	$^1S^e$	$^1P^o$	1:1	3:2	978.1	7.673E-01	1.79E+09
2s2	-2s3p	$^1S^e$	$^1P^o$	1:1	3:3	386.6	2.314E-01	3.45E+09
2s2	-2s3p	$^1S^e$	$^3P^o$	1:1	3:4	385.5	1.022E-04	1.53E+06
2s2	-2p3s	$^1S^e$	$^3P^o$	1:1	3:5	324.8	1.965E-05	4.15E+05
2s2	-2p3s	$^1S^e$	$^1P^o$	1:1	3:6	322.9	4.508E-02	9.63E+08
2s2	-2s4p	$^1S^e$	$^3P^o$	1:1	3:7	315.0	1.952E-07	4.38E+03
2s2	-2s4p	$^1S^e$	$^1P^o$	1:1	3:8	310.5	2.807E-02	6.49E+08
2s2	-2p3d	$^1S^e$	$^3D^o$	1:1	3:9	296.5	7.380E-07	1.87E+04
2s2	-2p3d	$^1S^e$	$^3P^o$	1:1	3:10	294.3	5.761E-07	1.48E+04
2s2	-2s5p	$^1S^e$	$^1P^o$	1:1	3:11	291.6	4.478E-02	1.17E+09
2s2	-2s5p	$^1S^e$	$^3P^o$	1:1	3:12	290.8	3.145E-07	8.29E+03
2s2	-2p3d	$^1S^e$	$^1P^o$	1:1	3:13	288.7	3.277E-03	8.76E+07
2s2	-2s6p	$^1S^e$	$^3P^o$	1:1	3:12	280.4	6.737E-10	1.91E+01
2s2	-2s6p	$^1S^e$	$^1P^o$	1:1	3:15	280.3	1.649E-02	4.67E+08
2s2	-2s7p	$^1S^e$	$^1P^o$	1:1	3:16	274.4	1.143E-02	3.38E+08
2s2	-2s8p	$^1S^e$	$^1P^o$	1:1	3:18	270.6	7.825E-03	2.38E+08
2s2p	-2p2	$^3P^o$	$^3P^e$	3:1	1:2	1177.3	9.221E-02	1.33E+09
2s2p	-2p2	$^3P^o$	$^3P^e$	1:1	3:1	1176.5	2.766E-01	4.45E+08
2s2p	-2p2	$^3P^o$	$^3P^e$	3:1	3:1	1176.8	6.918E-02	3.34E+08
2s2p	-2p2	$^3P^o$	$^3P^e$	5:1	3:1	1177.6	6.910E-02	5.55E+08
2s2p	-2p2	$^3P^o$	$^3P^e$	3:1	5:1	1176.2	1.153E-01	3.34E+08
2s2p	-2p2	$^3P^o$	$^3P^e$	5:1	5:1	1177.0	2.075E-01	1.00E+09

TABLE VI. Transitions in C III in *LS* Multiplet Order

See page 218 for Explanation of Tables

$Conf_i$	$Conf_k$	LS_i	LS_k	$g_i : n_i$	$g_k : n_k$	$\lambda(\text{\AA})$	f_{ik}	$A_{ki}(s^{-1})$
$2s2p$	$-2p2$	$^3P^o$	$^3P^e$	9 : 0	9 : 0	1176.8	2.766E-01	1.34E+09
$2s2p$	$-2p2$	$^1P^o$	$^3P^e$	3 : 2	1 : 2	2854.4	7.074E-08	1.74E+02
$2s2p$	$-2p2$	$^1P^o$	$^3P^e$	3 : 2	3 : 1	2851.7	1.649E-08	1.36E+01
$2s2p$	$-2p2$	$^1P^o$	$^3P^e$	3 : 2	5 : 1	2848.2	3.737E-06	1.85E+03
$2p2$	$-2s3p$	$^3P^e$	$^1P^o$	1 : 2	3 : 3	823.9	1.258E-08	4.13E+01
$2p2$	$-2s3p$	$^3P^e$	$^1P^o$	3 : 1	3 : 3	824.1	4.226E-08	4.16E+02
$2p2$	$-2s3p$	$^3P^e$	$^1P^o$	5 : 1	3 : 3	824.4	3.740E-07	6.13E+03
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	1 : 2	3 : 4	818.6	1.835E-04	6.10E+05
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	3 : 1	1 : 2	818.9	6.013E-05	1.80E+06
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	3 : 1	3 : 4	818.8	4.497E-05	4.48E+05
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	3 : 1	5 : 2	818.8	7.777E-05	4.65E+05
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	5 : 1	3 : 4	819.1	4.513E-05	7.49E+05
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	5 : 1	5 : 2	819.1	1.372E-04	1.37E+06
$2p2$	$-2s3p$	$^3P^e$	$^3P^o$	9 : 0	9 : 0	819.0	1.826E-04	1.82E+06
$2p2$	$-2p3s$	$^3P^e$	$^3P^o$	1 : 2	3 : 5	586.0	1.336E-01	8.67E+08
$2p2$	$-2p3s$	$^3P^e$	$^3P^o$	3 : 1	1 : 3	586.3	4.442E-02	2.59E+09
$2p2$	$-2p3s$	$^3P^e$	$^3P^o$	3 : 1	3 : 5	586.1	3.334E-02	6.49E+08
$2p2$	$-2p3s$	$^3P^e$	$^3P^o$	5 : 1	3 : 5	586.3	3.331E-02	1.08E+09
$2p2$	$-2p3s$	$^3P^e$	$^3P^o$	9 : 0	9 : 0	586.2	5.927E-02	1.15E+09
$2p2$	$-2p3s$	$^3P^e$	$^1P^o$	1 : 2	3 : 6	580.1	6.312E-05	4.18E+05
$2p2$	$-2p3s$	$^3P^e$	$^1P^o$	3 : 1	3 : 6	580.2	1.712E-05	3.40E+05
$2p2$	$-2p3s$	$^3P^e$	$^1P^o$	5 : 1	3 : 6	580.3	2.797E-05	9.25E+05
$2p2$	$-2s4p$	$^3P^e$	$^1P^o$	1 : 2	3 : 8	541.2	1.202E-07	9.15E+02
$2p2$	$-2s4p$	$^3P^e$	$^1P^o$	3 : 1	3 : 8	541.3	2.869E-08	6.55E+02
$2p2$	$-2s4p$	$^3P^e$	$^1P^o$	5 : 1	3 : 8	541.4	6.505E-07	2.47E+04