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R-MATRIX CALCULATION OF ELECTRON IMPACT EXCITATION OF FINE-STRUCTURE LEVELS OF Ne-LIKE IRON

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Electron impact collision strengths for transitions from the ground state to the fine-structure levels of the excited $2p^5 3s$, $2p^5 3p$, and $2p^5 3d$ configurations in Fe XVII are calculated using a Breit–Pauli *R*-matrix method. The results are presented at 70 and 200 Ry. We considered the lowest 15 *LS* $2s^2 2p^6(^1S)$, $2s^2 2p^5 3s(^{1,3}P^o)$, $2s^2 2p^5 3p(^{1,3}S, {}^{1,3}P, {}^{1,3}D)$, and $2s^2 2p^5 3d(^{1,3}P^o, {}^{1,3}D^o, {}^{1,3}F^o)$ states of Fe XVII in the present calculation. The 15 *LS* states give rise to 27 fine-structure levels which are represented by configuration-interaction wave functions. The relativistic effects are incorporated in the Breit–Pauli approximation by including one-body mass correction, Darwin, and spin–orbit interaction terms in the scattering equations. Our collision strengths are compared with those from other calculations. The excitation cross sections are integrated over a Maxwellian distribution of electron energies to give electron excitation rate coefficients over a wide temperature range from 250 to 1000 eV. The relative populations for different electron densities and temperatures are also presented.

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CONTENTS

INTRODUCTION

In recent years there has been great interest in the study of neon-like ions due to their wide application in laboratory and astrophysical plasmas [1–4]. The study of these ions has been of particular interest due to the possibility of achieving population inversion and thus laser amplification in transitions between the $2s^22p^53s$ and $2s^22p^53p$ configurations at VUV and soft x-ray wavelengths [2–4].

Several spectral lines of Fe XVII have been observed in the extreme ultraviolet (EUV) solar flare spectra by a slitless spectrograph in the Skylab manned space station [5, 6]. The $3s$–$3p$ and $3p$–$3d$ lines in Fe XVII have been identified in solar flare spectra [7–12]. Accurate atomic data such as radiative decay rates and electron excitation rate coefficients are needed for plasma diagnostics and also to develop soft x-ray lasers for Fe XVII.

Several calculations of electron impact excitation data for neon-like Fe XVII have been performed [13–24]. Most of the calculations are based on the distorted-wave approach [13–21]. However, Zhang et al. [22] have reported the fine-structure collision strengths in a Coulomb–Born exchange method. Ivanov et al. [23] used the uniform energy approach based on quantum electrodynamic (QED) theory to calculate the collision strengths and rate coefficients for neon-like argon, iron, and barium. Recently, Mohan et al. [24] calculated the fine-structure collision strengths of Fe XVII in the *R*-matrix method by including the term coupling coefficients in the semi-Breit–Pauli approximation.

Previously, a few calculations have been performed on neon-like ions using the *R*-matrix method [24–27], only one of which is on neon-like Fe XVII [24]. In the present work we have carried out a Breit–Pauli *R*-matrix calculation by including relativistic and resonance effects. The relativistic effects are included in the Breit–Pauli approximation via one-body mass correction, Darwin, and spin–orbit interaction terms in the scattering equations [28]. We considered the lowest 15 *LS* states of Fe XVII: $2s^22p^6(^1S)$, $2s^22p^53s(^{1,3}P^o)$, $2s^22p^53p(^{1,3}S,\ ^{1,3}P,\ ^{1,3}D)$, and $2s^22p^53d(^{1,3}P^o,\ ^{1,3}D^o,\ ^{1,3}F^o)$, which are represented by configuration interaction wave functions. The 15 *LS* states give rise to 27 fine-structure levels in the intermediate coupling scheme. The contribution of the higher partial waves, which may be particularly important for the electric-dipole-allowed transitions, is properly included.

Theoretical Atomic Data

The *LS* states $2s^22p^6(^1S)$, $2s^22p^53s(^{1,3}P^o)$, $2s^22p^53p(^{1,3}S,\ ^{1,3}P,\ ^{1,3}D)$ and $2s^22p^53d(^{1,3}P^o,\ ^{1,3}D^o,\ ^{1,3}F^o)$ considered here are represented by configuration-interaction (CI) wave functions of the form

$$\Psi(LS\pi) = \sum_{i=1}^{M} a_i \phi_i(\alpha_i LS\pi), \qquad (1)$$

where each ϕ_i is constructed from one-electron orbitals whose angular momenta are coupled in a manner defined by α_i to form a total L and S common to all M configurations in Eq. (1).

The radial part of each orbital is written as a linear combination of normalized Slater-type orbitals

$$P_{nl} = \sum_{i=1}^{N} C_i[(2\xi_i)^{2p_i+1}/(2p_i)!]^{1/2} r^{p_i} \exp(-\xi_i r). \quad (2)$$

The parameters C_i, ξ_i and p_i in Eq. (2) are determined variationally as described by Hibbert [29].

Here we have used the six orthogonal one-electron orbitals $1s$, $2s$, $2p$, $3s$, $3p$, and $3d$. The $1s$, $2s$, and $2p$ radial functions are taken as the Hartree–Fock orbitals for neon-like Fe ion given by Clementi and Roetti [30] for the ground $1s^2 2s^2 2p^6$ state of Fe XVII. The parameters for the $3s$, $3p$, and $3d$ orbitals are obtained by optimizing the energy on the average of the $3s(^1P^o)$ and $3s(^3P^o)$ states, on the $3p(^3D)$ state and on the $3d(^3F^o)$ state using the configuration interaction code CIV3 of Hibbert [29]. In all cases we chose $N = n - l$ so that the coefficients are uniquely specified by the orthogonality conditions on P_{nl}. In this calculation, we considered the $1s^2 2s^2(2p^6)$, $1s^2 2s^2(2p^5)3s$, $3p$, $3d$ configurations in the CI expansion. The optimized parameters are displayed in Table I.

Next, we constructed the J-dependent CI wave functions by using expansions of the form [31]

$$\Psi_i(JM_J) = \sum_{j=1}^{K} b_{ij}\phi_j(\alpha_j L_j S_j J M_J), \quad (3)$$

where each of the K single-configuration functions ϕ_j is constructed from one-electron functions and α_j specifies the angular momentum coupling scheme of the jth configuration, and the orbital L_j and the spin S_j angular momenta are coupled to give the total angular momentum J. The mixing coefficients b_{ij} are obtained by diagonalizing the Breit–Pauli Hamiltonian with respect to the basis ϕ_j. The Breit–Pauli Hamiltonian here consists of the nonrelativistic term plus the one-body mass correction, Darwin term, and spin–orbit, spin–other–orbit, and spin–spin operators. The wave functions given by Eq. (3) are then used to calculate the excitation energies of the 27 fine-structure levels displayed in Table II.

In Table II our calculated fine-structure energies relative to the ground state are compared with the experimental results compiled by Sugar and Corliss [32] and the calculations of Bhatia and Doschek [19], Whitten et al. [33], Zhang et al. [22], Cornille et al. [21], and Hibbert et al. [34]. Our energy values for all the 26 excited levels agree within 0.5% of the measured values and are in close agreement with the other theoretical results. The energy ordering of our calculated values for the $2p^5 3d(^3F_4)$ and $2p^5 3d(^3P_2)$ levels do not agree with the measurement, however. The results of Bhatia and Doschek [19], Whitten et al. [33], and Zhang et al. [22] also show similar disagreement with the measurement for this pair of levels, the energy difference between which is very small. The results of Hibbert et al. [34] are in best agreement with the measured values because they used a large CI expansion and their *ab initio* energies were adjusted with the experimental energies. In the present work, our main aim is first to perform a Breit–Pauli R-matrix calculation for the collision strengths and then to derive the excitation rates and relative populations of the levels over wide temperature ranges. These data are rather impractical to obtain with a large CI expansion.

The scattering wave function for each total angular momentum J and parity π combination is expanded in the inner region ($r \le a$) in the R-matrix basis as [35, 36]

$$\Psi_k(J\pi) = A \sum_{ij} C_{ijk}\Phi_i^J(x_1, x_2, \ldots, x_N; r_{N+1}, \sigma_{N+1})u_{ij}(r_{N+1}) + \sum_j d_{jk}\phi_j^J(x_1, x_2, \ldots, x_{N+1}), \quad (4)$$

where A is an antisymmetrization operator, Φ_i^J are channel functions representing the 27 fine-structure atomic levels coupled with the angular and spin functions of the scattered electron to form channel functions of J and π. The ϕ_j^J are $(N+1)$-electron configurations constituted from the atomic orbitals and are included to ensure completeness of the total wave function expansion and to allow for short-range correlation; u_{ij} are the orthogonal set of continuum basis orbitals. The coefficients C_{ijk} and d_{jk} are obtained by diagonalizing the $(N+1)$-electron Breit–Pauli Hamiltonian in the inner region. In this scattering calculation, the Breit–Pauli corrections included in the Hamiltonian consisted of one-body mass correction, Darwin, and spin–orbit interaction terms. We have chosen the boundary radius $a = 2.6$ a.u. Twelve continuum orbitals for each angular momentum are included to obtain convergence within the energy range of interest. The maximum number of channels that are retained in the first expansion in Eq. (4) is 109. The number of bound 11-electron configurations retained in the second expansion depends on J and parity π; all possible configurations consistent with 2 electrons outside a $1s^2 2s^2 2p^5$ core are retained. The maximum size of the collision Hamiltonian is 1750 for the symmetry $J = 9/2$ odd. The coupled equations are solved using a perturbation method developed by Seaton [37] to yield K matrices and then the collision strengths. The R-matrix method is used to

calculate partial collision strengths from $J = 0.5$ to $J = 9.5$. The contributions from the higher partial waves needed for the dipole-allowed transitions are calculated using the Bethe approximation [38].

In Table III our total collision strengths at incident electron energies of 70 and 200 Ry are presented for all transitions from the ground state. These energies are above the highest threshold, where resonances do not occur, and we expect our results to be close to the distorted-wave and other calculations. At 70 Ry, we compare our results with the distorted-wave calculation of Cornille et al. [21]; we also include the results of Bhatia and Doschek [19] obtained at 76.83 Ry. There is reasonably good agreement among all the calculations. At 200 Ry, our results are compared with the distorted-wave calculation of Cornille et al. [21] and the *R*-matrix calculation of Mohan et al. [24]. At this higher energy, our results agree very well with the distorted-wave calculation of Cornille et al. [21]. However, the *R*-matrix results of Mohan et al. [24] differ significantly from ours and from the distorted-wave calculation [21] for many transitions.

The excitation rate coefficient for a transition from a lower level i to an upper level f at a temperature T_e (in K) is given by [39]

$$C(i \rightarrow f) = \frac{8.63 \times 10^{-6}}{g_i T_e^{1/2}} \times \int_{\Delta E_{if}}^{\infty} \Omega_E(i \rightarrow f) \exp(-E/(kT_e)) d(E/(kT_e)), \quad (5)$$

where $g_i = (2J_i + 1)$ is the statistical weight of the lower level i, $\Delta E_{if} = E_f - E_i$ is the transition energy, $\Omega_E(i \rightarrow f)$ is the collision strength, k is the Boltzmann constant, and E is the electron impact energy. Similar to the earlier work on neon-like selenium [25], in this calculation also complicated resonance structures characterize the collision strengths for many transitions within the threshold region. These resonances dominate the low-energy excitation cross sections and enhance the excitation rate coefficients considerably at low temperatures. We chose a fine mesh of 0.005 Ry in this energy region and calculated the total collision strengths at 1428 energy points to fully account for the resonance structure. The electron excitation rate coefficients are then obtained by integrating these total collision strengths over a Maxwellian distribution of electron energies as given by Eq. (5). In Table IV we present our excitation rates from the ground state at electron temperatures of 250, 600, and 1000 eV.

Finally, the level populations N_j are calculated by solving the 27 coupled rate equations [40]

$$N_j[\sum_{i<j} A_{ji} + n_e(\sum_{i<j} C_{ji}^d + \sum_{i>j} C_{ji}^e)] = n_e(\sum_{i<j} N_i C_{ij}^e + \sum_{i>j} N_i C_{ij}^d) + \sum_{i>j} N_i A_{ij}, \quad (6)$$

where C_{ij} are the electron excitation rate coefficients, the superscripts e and d refer to the excitation and deexcitation respectively, and n_e is the electron density. In our calculation, we have used our A values and the electron collisional rates. We considered all transitions among the lowest 27 fine-structure levels. The relative populations are normalized so that the sum of the level populations is unity. In Table V are tabulated our results for relative populations for a wide range of electron temperatures (250–1000 eV) and electron densities (10^{18}–10^{22}). There are neither measurements nor other calculations to which our results may be compared.

In summary, in this paper we have presented energy levels, collision strengths from the ground state, and electron excitation rate coefficients for the lowest 27 fine-structure levels of Fe XVII calculated in the Breit–Pauli *R*-matrix approach. We took into account the detailed resonance structure in the calculation of electron excitation rate coefficients. The use of our larger electron excitation rates compared to the other calculations makes the ratios of the level populations tend toward their statistical weight at higher electron densities [25]. We have also presented the relative level populations of the fine-structure levels of Fe XVII at a range of electron temperatures and densities appropriate to the condition inside laser-produced plasmas.

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EXPLANATION OF TABLES

TABLE I. Radial Function Parameters for Optimized Orbitals of Fe XVII

Orbital	The one-electron orbitals in spectroscopic notation (see Eq. (2)).
Coefficients	The expansion coefficients C_i of the (unnormalized) Slater-type orbitals.
Powers	The powers p_i of r in the Slater-type orbitals.
Exponents	The exponents ξ_i of the Slater-type orbitals.

TABLE II. Calculated and Experimental Energy Levels (in a.u.) of Fe XVII Relative to the Ground State

Level	Configuration and term of levels.
Present	Present calculated values.
Expt.	Experimental values of Sugar and Corliss [32].
BD	37-States calculation of Bhatia and Doschek [19].
WHMI	37-States calculation of Whitten et al. [33].
ZSCM	89-States calculation of Zhang et al. [22].
CDFBB	89-States calculation of Cornille et al. [21].
HDM	37-States calculation of Hibbert et al. [34].
	1 a.u. = 219,474 cm^{-1}.

TABLE III. Comparison of Fine-Structure Collision Strengths for Fe XVII Initially in Its Ground State

Present	Present results of Breit–Pauli R-matrix calculation at 70 and 200 Ry.
CDFBB	Distorted-wave results of Cornille et al. [21] at 70 and 200 Ry.
BD	Distorted-wave results of Bhatia and Doschek [19] at 76.8 Ry.
MSE	R-matrix calculation of Mohan et al. [24] at 200 Ry.

TABLE IV. Excitation Rates (in $cm^3\ s^{-1}$) for Fe XVII at 250, 600, and 1000 eV

TABLE V. Relative Level Populations for Fe XVII at Different Electron Temperatures and Electron Densities

T_e	Electron temperature.
n_e	Electron density (in cm^{-3}).

TABLE I. Radial Function Parameters for Optimized Orbitals of Fe XVII

See page 262 for Explanation of Tables

Orbital	Coefficients	Powers	Exponents
3s	37.41485	1	19.46021
	-241.80316	2	8.26400
	400.80895	3	6.25177
3p	246.99607	2	10.60915
	-230.50839	3	5.79574
3d	241.04682	3	6.13424

TABLE II. Calculated and Experimental Energy Levels (in a.u.) of Fe XVII Relative to the Ground State

See page 262 for Explanation of Tables

Level		Present	Expt. [32]	BD [19]	WHMI [33]	ZSCM [22]	CDFBB [21]	HDM [34]
$2p^6$	$^1S_0$	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$2p^5$ 3s	$^3P_2$	26.6762	26.6483	26.6805	26.6500	26.6431	26.6649	26.6518
	$^1P_1$	26.7434	26.7184	26.7533	26.7217	26.7079	26.7378	26.7213
	$^3P_0$	27.1344	27.1134	27.1399	27.1156	27.1093	27.1270	27.1137
	$^3P_1$	27.1760	27.1570	27.1877	27.1612	27.1498	27.1749	27.1585
$2p^5$ 3p	$^3S_1$	27.8241	27.7609	27.7895	27.7606	27.7824	27.7708	27.7622
	$^3D_2$	27.9278	27.8894	27.9243	27.8918	27.8908	27.9087	27.8981
	$^3D_3$	27.9764	27.9487	27.9807	27.9506	27.9502	27.9660	27.9528
	$^1P_1$	28.0224	27.9902	28.0237	27.9936	27.9862	28.0091	27.9949
	$^3P_2$	28.0816	28.0569	28.0892	28.0586	28.0458	28.0750	28.0597
	$^3P_0$	28.2952	28.2578	28.2994	28.2637	28.2489	28.2850	28.2687
	$^3D_1$	28.3663	28.3336	28.3660	28.3379	28.3396	28.3530	28.3413
	$^3P_1$	28.4778	28.4531	28.4808	28.4555	28.4500	28.4688	28.4543
	$^1D_2$	28.4878	28.4669	28.4968	28.4702	28.4652	28.4851	28.4697
	$^1S_0$	29.0820	28.9447	29.0826	29.0152	28.9363	29.0457	28.9677
$2p^5$ 3d	$^3P_0$	29.5092	29.4492	29.4861	29.4532	29.4608	29.4653	29.4494
	$^3P_1$	29.5433	29.4909	29.5247	29.4885	29.4959	29.5047	29.4863
	$^3F_4$	29.6051	29.5521	29.5970	29.5561	29.5602	29.5874	29.5611
	$^3P_2$	29.6084	29.5489	29.6064	29.5598	29.5633	29.5785	29.5537
	$^3F_3$	29.6331	29.5806	29.6271	29.5888	29.5866	29.6084	29.5909
	$^1D_2$	29.6974	29.6438	29.6895	29.6524	29.6431	29.6725	29.6517
	$^3D_3$	29.7379	29.6833	29.7369	29.6914	29.6818	29.7213	29.6919
	$^3D_1$	29.9145	29.8540	29.9080	29.8659	29.8490	29.8921	29.8645
	$^3F_2$	30.0888	30.0439	30.0840	30.0530	30.0486	30.0683	30.0485
	$^3D_2$	30.1228	30.0809	30.1199	30.0817	30.0763	30.1061	30.0759
	$^1F_3$	30.1399	30.0987	30.1429	30.1026	30.0982	30.1287	30.0975
	$^1P_1$	30.4423	30.3452	30.4328	30.3760	30.3532	30.4150	30.3698

TABLE III. Comparison of Fine-Structure Collision Strengths for Fe XVII Initially in Its Ground State

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Transition from Ground State to		70 Ry		76.83 Ry	200 Ry		
		Present	CDFBB [21]	BD [19]	Present	CDFBB [21]	MSE [24]
$2p^5$ 3s	$^3P_2$	1.54(-3)	1.51(-3)	1.35(-3)	3.78(-4)	3.85(-4)	4.20(-4)
	$^1P_1$	2.55(-3)	2.12(-3)	2.44(-3)	7.67(-3)	6.58(-3)	3.95(-3)
	$^3P_0$	3.09(-4)	3.03(-4)	2.73(-4)	7.59(-5)	7.70(-5)	8.00(-5)
	$^3P_1$	2.13(-3)	2.03(-3)	2.27(-3)	5.74(-3)	5.96(-3)	4.52(-3)
$2p^5$ 3p	$^3S_1$	3.53(-3)	3.86(-3)	3.55(-3)	9.15(-4)	9.91(-4)	1.12(-3)
	$^3D_2$	3.40(-3)	3.62(-3)	3.58(-3)	3.39(-3)	2.98(-3)	1.82(-3)
	$^3D_3$	4.34(-3)	4.31(-3)	3.89(-3)	9.40(-4)	8.83(-4)	1.03(-3)
	$^1P_1$	1.59(-3)	1.54(-3)	1.37(-3)	3.45(-4)	2.98(-4)	4.40(-4)
	$^3P_2$	2.88(-3)	3.13(-3)	3.18(-3)	3.49(-3)	3.10(-3)	2.04(-3)
	$^3P_0$	4.28(-3)	3.15(-3)	3.14(-3)	2.51(-3)	3.18(-3)	3.43(-3)
	$^3D_1$	1.66(-3)	1.67(-3)	1.47(-3)	3.64(-4)	3.30(-4)	3.90(-4)
	$^3P_1$	1.72(-3)	1.72(-3)	1.56(-3)	3.80(-4)	3.56(-4)	4.00(-4)
	$^1D_2$	3.30(-3)	3.76(-3)	3.83(-3)	3.80(-3)	3.67(-3)	1.79(-3)
	$^1S_0$	4.74(-2)	4.54(-2)	4.57(-2)	5.74(-2)	5.38(-2)	4.79(-2)
$2p^5$ 3d	$^3P_0$	1.87(-3)	1.91(-3)	1.66(-3)	3.41(-4)	3.44(-4)	3.90(-4)
	$^3P_1$	5.65(-3)	5.68(-3)	5.03(-3)	1.78(-3)	1.64(-3)	1.72(-3)
	$^3F_4$	6.61(-3)	6.64(-3)	6.50(-3)	1.03(-3)	1.02(-3)	1.13(-3)
	$^3P_2$	7.29(-3)	7.53(-3)	5.69(-3)	1.28(-3)	1.31(-3)	1.49(-3)
	$^3F_3$	4.68(-3)	4.07(-3)	4.32(-3)	2.78(-3)	2.52(-3)	2.14(-3)
	$^1D_2$	2.69(-3)	2.76(-3)	2.31(-3)	3.53(-4)	3.51(-4)	6.90(-4)
	$^3D_3$	3.29(-3)	3.36(-3)	3.16(-3)	2.92(-3)	2.64(-3)	2.41(-3)
	$^3D_1$	2.59(-2)	2.22(-2)	2.52(-2)	4.99(-2)	4.68(-2)	4.01(-2)
	$^3F_2$	3.14(-3)	3.14(-3)	2.68(-3)	4.50(-4)	4.39(-4)	4.00(-4)
	$^3D_2$	4.10(-3)	4.10(-3)	3.52(-3)	6.25(-4)	6.14(-4)	4.90(-4)
	$^1F_3$	4.00(-3)	4.07(-3)	3.83(-3)	3.16(-3)	2.97(-3)	2.14(-3)
	$^1P_1$	1.04(-1)	9.88(-2)	1.06(-1)	2.11(-1)	2.21(-1)	1.66(-1)

TABLE IV. Excitation Rates (in $cm^3\ s^{-1}$) for Fe XVII at 250, 600, and 1262 eV
See page 262 for Explanation of Tables

Transition from Ground State to		T_e=250 eV	T_e=600 eV	T_e=1000 eV
$2p^5\ 3s$	$^3P_2$	2.213(-12)	3.918(-12)	3.307(-12)
	$^1P_1$	2.854(-12)	6.658(-12)	7.957(-12)
	$^3P_0$	3.432(-13)	6.498(-13)	5.635(-13)
	$^3P_1$	2.483(-12)	5.707(-12)	6.573(-12)
$2p^5\ 3p$	$^3S_1$	1.342(-12)	3.367(-12)	3.330(-12)
	$^3D_2$	1.270(-12)	4.139(-12)	7.188(-12)
	$^3D_3$	1.451(-12)	3.741(-12)	3.709(-12)
	$^1P_1$	8.279(-13)	1.876(-12)	1.758(-12)
	$^3P_2$	1.002(-12)	3.246(-12)	4.388(-12)
	$^3P_0$	1.338(-12)	4.023(-12)	4.528(-12)
	$^3D_1$	9.801(-13)	2.169(-12)	2.006(-12)
	$^3P_1$	7.889(-13)	1.871(-12)	1.785(-12)
	$^1D_2$	1.207(-12)	3.779(-12)	4.870(-12)
	$^1S_0$	1.094(-11)	4.533(-11)	6.078(-11)
$2p^5\ 3d$	$^3P_0$	3.665(-13)	1.150(-12)	1.207(-12)
	$^3P_1$	1.138(-12)	3.700(-12)	4.090(-12)
	$^3F_4$	1.265(-12)	3.937(-12)	4.091(-12)
	$^3P_2$	1.415(-12)	4.444(-12)	4.658(-12)
	$^3F_3$	9.382(-13)	3.380(-12)	4.225(-12)
	$^1D_2$	5.296(-13)	1.597(-12)	1.632(-12)
	$^3D_3$	6.627(-13)	2.592(-12)	3.365(-12)
	$^3D_1$	5.291(-12)	2.650(-11)	4.098(-11)
	$^3F_2$	5.567(-13)	1.774(-12)	1.851(-12)
	$^3D_2$	7.361(-13)	2.350(-12)	2.459(-12)
	$^1F_3$	7.490(-13)	2.977(-12)	3.828(-12)
	$^1P_1$	2.045(-11)	1.082(-10)	1.701(-10)

TABLE V. Relative Level Populations for Fe XVII at Different Electron Temperatures and Electron Densities

See page 262 for Explanation of Tables

Level		T_e=250 eV			T_e=600 eV			T_e=1000 eV		
		n_e=10^{18}	10^{20}	10^{22}	10^{18}	10^{20}	10^{22}	10^{18}	10^{20}	10^{22}
$2p^6$	$^1S_0$	9.86(-2)	9.28(-1)	5.31(-1)	9.59(-1)	7.95(-1)	2.26(-1)	9.55(-1)	7.65(-1)	1.77(-1)
$2p^5$ 3s	$^3P_2$	5.24(-3)	5.45(-3)	2.85(-2)	1.45(-2)	1.34(-2)	4.09(-2)	1.56(-2)	1.46(-2)	4.16(-2)
	$^1P_1$	2.05(-5)	1.30(-3)	1.65(-2)	6.18(-5)	3.23(-3)	2.37(-2)	7.50(-5)	3.70(-3)	2.43(-2)
	$^3P_0$	5.41(-4)	8.02(-4)	5.16(-3)	1.35(-3)	1.94(-3)	7.62(-3)	1.24(-3)	2.05(-3)	7.84(-3)
	$^3P_1$	1.82(-5)	1.31(-3)	1.54(-2)	5.72(-5)	3.42(-3)	2.29(-2)	6.97(-5)	3.93(-3)	2.36(-2)
$2p^5$ 3p	$^3S_1$	1.01(-3)	2.81(-3)	1.50(-2)	2.99(-3)	7.35(-3)	2.32(-2)	3.31(-3)	8.08(-3)	2.41(-2)
	$^3D_2$	9.83(-4)	3.87(-3)	2.45(-2)	2.99(-3)	1.05(-2)	3.82(-2)	3.63(-3)	1.23(-2)	4.00(-2)
	$^3D_3$	2.03(-3)	6.70(-3)	3.46(-2)	5.98(-3)	1.82(-2)	5.41(-2)	6.55(-3)	2.02(-2)	5.64(-2)
	$^1P_1$	2.60(-4)	1.75(-3)	1.41(-2)	6.77(-4)	4.49(-3)	2.21(-2)	7.34(-4)	5.08(-3)	2.32(-2)
	$^3P_2$	8.06(-4)	3.99(-3)	2.42(-2)	2.41(-3)	1.09(-2)	3.81(-2)	2.77(-3)	1.24(-2)	3.99(-2)
	$^3P_0$	1.05(-4)	5.72(-4)	4.41(-3)	3.08(-4)	1.56(-3)	6.99(-3)	3.45(-4)	1.76(-3)	7.41(-3)
	$^3D_1$	3.60(-4)	1.82(-3)	1.33(-2)	9.42(-4)	4.77(-3)	2.13(-2)	9.20(-4)	5.28(-3)	2.25(-2)
	$^3P_1$	3.77(-4)	2.02(-3)	1.34(-2)	1.02(-3)	5.39(-3)	2.15(-2)	9.66(-4)	5.80(-3)	2.27(-2)
	$^1D_2$	2.88(-4)	2.87(-3)	2.25(-2)	8.99(-4)	8.08(-3)	3.63(-2)	1.13(-3)	9.43(-3)	3.82(-2)
	$^1S_0$	3.11(-4)	1.86(-3)	4.45(-3)	1.26(-3)	6.74(-3)	7.71(-3)	1.68(-3)	8.56(-3)	8.28(-3)
$2p^5$ 3d	$^3P_0$	6.64(-5)	8.22(-4)	4.19(-3)	2.02(-4)	2.43(-3)	7.21(-3)	2.26(-4)	2.69(-3)	7.72(-3)
	$^3P_1$	2.76(-5)	1.78(-3)	1.23(-2)	8.33(-5)	5.12(-3)	2.13(-2)	9.42(-5)	5.74(-3)	2.29(-2)
	$^3F_4$	4.79(-4)	7.08(-3)	3.73(-2)	1.42(-3)	2.15(-2)	6.48(-2)	1.58(-3)	2.45(-2)	6.96(-2)
	$^3P_2$	2.53(-4)	3.67(-3)	2.06(-2)	7.71(-4)	1.09(-2)	3.57(-2)	8.65(-4)	1.25(-2)	3.83(-2)
	$^3F_3$	2.45(-4)	4.63(-3)	2.86(-2)	7.78(-4)	1.41(-2)	4.97(-2)	9.43(-4)	1.69(-2)	5.37(-2)
	$^1D_2$	1.14(-4)	2.77(-3)	1.99(-2)	3.31(-4)	8.05(-3)	3.46(-2)	3.73(-4)	9.38(-3)	3.74(-2)
	$^3D_3$	2.20(-4)	4.73(-3)	2.84(-2)	6.94(-4)	1.45(-2)	4.97(-2)	8.21(-4)	1.70(-2)	5.36(-2)
	$^3D_1$	1.03(-6)	1.54(-4)	9.76(-3)	4.82(-6)	5.45(-4)	1.74(-2)	7.29(-6)	7.51(-4)	1.93(-2)
	$^3F_2$	1.03(-4)	2.54(-3)	1.86(-2)	2.95(-4)	7.54(-3)	3.31(-2)	3.03(-4)	8.60(-3)	3.60(-2)
	$^3D_2$	1.28(-4)	2.83(-3)	1.87(-2)	3.76(-4)	8.59(-3)	3.36(-2)	3.86(-4)	9.64(-3)	3.64(-2)
	$^1F_3$	1.04(-4)	3.49(-3)	2.63(-2)	3.65(-4)	1.10(-2)	4.73(-2)	4.61(-4)	1.32(-2)	5.13(-2)
	$^1P_1$	8.25(-7)	9.97(-5)	7.59(-3)	4.19(-6)	4.23(-4)	1.45(-2)	6.53(-6)	6.19(-4)	1.65(-2)