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CHIANTI—AN ATOMIC DATABASE FOR EMISSION LINES. IV. EXTENSION TO X-RAY WAVELENGTHS

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ABSTRACT

CHIANTI provides a database of atomic energy levels, wavelengths, radiative transition probabilities, and electron excitation data for a large number of ions of astrophysical interest. It also includes a suite of Interactive Data Language programs to calculate optically thin synthetic spectra and to perform spectral analysis and plasma diagnostics. This database allows the calculation of theoretical line emissivities necessary for the analysis of optically thin emission-line spectra. The first version (1.01) of the CHIANTI database was released in 1996 and published by Dere et al. in 1997 as Paper I in this series. The second version, released in 1999 by Landi et al., included continuum emission and data for additional ions. Both versions of the CHIANTI database have been used extensively by the astrophysical and solar communities to analyze emission-line spectra from astrophysical sources. Now the CHIANTI database has been extended to wavelengths shorter than 50 Å by including atomic data for the hydrogen and helium isoelectronic sequences, inner-shell transitions and satellite lines, and several other ions. In addition, some of the ions already present in the database have been updated and extended with new atomic data from published calculations.

Subject headings: atomic data — stars: atmospheres — Sun: atmosphere

1. INTRODUCTION

This paper describes the extension of the CHIANTI database (Dere et al. 1997, Paper I) to the X-ray portion of the electromagnetic spectrum. This release of the database is referred to as version 3.0. The CHIANTI database consists of assessed values of atomic energy levels, weighted oscillator strengths (*gf*-values), spontaneous radiative decay rates (*A*-values), and electron collisional excitation rates which are needed to calculate the spectrum of astrophysical plasmas. In addition, a package of Interactive Data Language (IDL) procedures to perform the spectral calculation are also available. In Paper II, Young, Landi, & Thomas (1998) used the CHIANTI database for a detailed comparison with observed EUV solar spectra to assess the diagnostic accuracy of the two data sets. In Paper III, Landi et al. (1999) described the inclusion of many of the minor ions (Na, P, Cl, K, Ti, Cr, Mn, Co, and Zn) in the CHIANTI database as well as several other ions and a routine for the calculation of the continuum.

The extension of the CHIANTI database to X-ray wavelengths primarily involves the incorporation of the hydrogen-like and helium-like isoelectronic sequences and their satellites. The inclusion of the satellites has required a significant modification to the manner in which the spectra have been calculated with CHIANTI. Consequently, a new version of the IDL package, also labeled "version 3.0," has been produced. In addition, data from several other ions are either new to the database or have been updated and these are also described. Tables 1 and 2 show the ions that are included in the database and Tables 3 and 4 show the temperature of maximum ionization fraction for these ions.

In order to check the accuracy of the database, a detailed comparison between the predictions of the CHIANTI database and observed spectra in the 1–50 Å wavelength range has been made. This consisted of first compiling a list of observed spectral lines identified in high-resolution spectra observed primarily in solar flares. This comparison prompted a detailed reassessment of the energy levels of the Fe XVI through Fe XXVI ions responsible for many of the strongest emission lines in this spectral region. With the help of ab initio calculations of the atomic structure of these ions that we performed and a recent compilation of the iron ion energy levels by the NIST group (Shirai et al. 2000), we were able to improve many of the energy level assignments and line identifications for the CHIANTI database. However, this study also suggested that further work is necessary to understand the spectra from the highly ionized iron ions. A summary of this comparison is presented in Table 5 as a complete listing of observed high-resolution spectra in the 1–50 Å wavelength region and the corresponding identification of these lines in the CHIANTI database.[1]

[1] The CHIANTI database and associated IDL procedures, now distributed as version 3.0, are freely available at the following addresses on the World Wide Web: http://wwwsolar.nrl.navy.mil/chianti.html, http://www.arcetri.astro.it/science/chianti/chianti.html, and http://www.damtp.cam.ac.uk/user/astro/chianti/chianti.html.

TABLE 1

IONS INCLUDED IN THE CHIANTI DATABASE

Ion	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
H.....																
He		●														
C.....		●	○	●	*	*										
N.....		○	○	●	●	*	*									
O.....		●	○	○	●	○	*	*								
Ne		●	●	○	○	○	●	○	*	*						
Na			●	○	●	○	○	●	●	*	*					
Mg.....		●		●	○	●	○	○	○	○	*	*				
Al			●		●	●	●	○	○	●	○	*	*			
Si.....		○	●	●	●	●	●	○	○	○	●	○	*	*		
P					●		●	●	●	○	○	●	●			
S		●	*	○	●	●	●	●	●	○	○	○	●	○	*	*
Cl														●		
Ar							●	●	○	●	●	○	○	○	●	○
K.....								●	●		●	●	●	○	●	●
Ca									●	●	○	●	●	○	○	○
Ti											●	●		●	●	●
Cr													●	●		●
Mn.....															●	
Fe.....		●					●	○	●	○	○	●	○	○	●	●
Co																
Ni.....												●	●		○	●
Zn																

NOTE.—Ions included in the CHIANTI database. Filled dots: ions in CHIANTI version 2.0 *not* changed in the present update. Open dots: ions in the CHIANTI version 2.0 whose data have been modified/complemented in the present update. Asterisks: new entries for the CHIANTI database.

2. EXCITATION OF X-RAY SATELLITE LINES

In previous versions of CHIANTI, spectral lines were produced by electron collisional excitation of ions followed by the radiative decay of the excited level. An important aspect of the X-ray spectral region is the existence of numerous satellite lines to many of the strong resonance lines. These lines are produced in two ways: by the excitation of inner-shell electrons to levels above the ionization potential or by the dielectronic capture of an incident electron into a similar excited level. In both cases, the excited level either undergoes a radiative decay to a lower energy level of the ion or an autoionizing transition to the next ionization stage. Neither of these two-step processes fit into the framework of earlier versions of CHIANTI. A rigorous treatment would require the simultaneous solution of combined ionization and level populations for all of the ions of a given element. However, such a computationally demanding treatment is not required and an approximate treatment of these processes is used for the version of CHIANTI described in this paper.

Most, if not all, past treatments of satellite lines are based on the two-level approximation where only the ground level is populated and all lines are produced by collision excitation from this level to a higher level which undergoes a rapid radiative transition. The approach used in CHIANTI is to solve the steady-state rate equation for populations of all the levels in a given ion in order to take into account the population of metastable levels above the ground level. Since none of the autoionizing levels that give rise to the satellite lines reach a significant population, it is possible to include these levels separately from those below the ionization potential.

TABLE 2

IONS INCLUDED IN THE CHIANTI DATABASE

Ion	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII
Ar.....	*	*										
K.....	●											
Ca	●	○	*	*								
Ti	○	○	●	●								
Cr.....	●	●	●	○	●	●						
Mn.....	○	●	●	○	○	●	●					
Fe.....	○	●	●	●	○	○	●	○	*	*		
Co	●		●		●	●	○	●	●			
Ni.....	●	●	○	●		●	○	○	●	○	*	*
Zn				●				●	○	●	●	

NOTE.—Ions included in the CHIANTI database. Filled dots: ions in CHIANTI version 2.0 *not* changed in the present update. Open dots: ions in CHIANTI version 2.0 whose data have been modified/complemented in the present update. Asterisks: new entries for the CHIANTI database.

TABLE 3

TEMPERATURE OF MAXIMUM ABUNDANCE FOR IONS INCLUDED IN THE CHIANTI DATABASE

Ion	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
H.....															
He	4.66														
C.....	4.36	4.85	5.02	5.43	6.00										
N.....	4.47	4.90	5.16	5.28	5.74	6.19									
O.....	4.52	4.96	5.22	5.39	5.48	5.90	6.37								
Ne	4.55	4.94	5.23	5.45	5.62	5.71	5.80	6.15	6.64						
Na		4.96	5.20	5.44	5.64	5.78	5.86	5.92	6.30	6.77					
Mg.....	4.08		5.23	5.43	5.63	5.80	5.90	5.99	6.05	6.45	6.89				
Al		4.56		5.37	5.60	5.77	5.91	6.02	6.10	6.17	6.55	7.00			
Si.....	4.15	4.46	4.79	5.16	5.54	5.76	5.90	6.03	6.12	6.20	6.28	6.66	7.09		
P				5.11		5.74	5.91	6.04	6.16	6.23	6.30	6.36			
S	4.24	4.67	5.02	5.19	5.28	5.51	5.86	6.00	6.12	6.24	6.31	6.39	6.44	6.86	7.29
Cl													6.47		
Ar.....						5.50	5.58	5.75	6.08	6.20	6.31	6.41	6.49	6.54	6.62
K.....							5.70	5.73		6.19	6.31	6.41	6.50	6.58	6.61
Ca								5.79	5.81	5.95	6.25	6.38	6.48	6.56	6.61
Ti										6.01	6.09		6.45	6.56	6.64
Cr.....												6.20	6.24		6.60
Mn.....														6.32	
Fe.....	4.11					5.41	5.57	5.80	5.99	6.07	6.13	6.20	6.27	6.32	6.42
Co															
Ni.....											6.24	6.29		6.37	6.40
Zn															

NOTE.—Temperature of the maximum ion abundance for the ions included in the CHIANTI database. Ion fractions come from Arnaud & Raymond (1992) for the Fe ions, Landini & Monsignori Fossi (1991) for the minor ions, Arnaud & Rothenflug (1985) for the other ions.

2.1. *Inner-Shell Excitation*

In the case of satellite lines produced by inner-shell excitations, the treatment is relatively straightforward. The collisional excitation and radiative decay is prescribed by the usual collision strengths and radiative A-values as described in Paper I. The only aspect that requires a modification to the standard CHIANTI model ion is the necessity of accounting for autoionizing transitions of the levels above the ionization potential. The rate of these transitions is given by the autoionization rate (a constant). The current model of CHIANTI does not consider transitions between ions. The incorporation of these inter-ion transitions in a proper manner can only be done at the cost of a very significant increase in computational time for little return in enhanced diagnostic capability. Consequently, autoionizing transitions are treated as radiative decays to the ground level of the ion from which they were excited but with no emission of radiation. This treatment allows us to take into account autoionization effect while avoiding the computational complexity of transitions between ions and with negligible effects on the overall ion level populations. The effect of these autoionizing transitions on the ionization balance is already accounted for in current calculations of ionization equilibrium, e.g., Arnaud & Rothenflug (1985).

2.2. *Dielectronic Excitation*

The collisional excitation rate of lines produced by dielectronic recombination is typically determined by considerations of detailed balance (Gabriel & Paget 1972). The ratio of the collisional rate coefficient for dielectronic excitation C_d to the total autoionization radiative decay rate A_a is

TABLE 4

TEMPERATURE OF MAXIMUM ABUNDANCE FOR IONS INCLUDED IN THE CHIANTI DATABASE

Ion	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII
Ar.....	6.94	7.46										
K.....	6.69											
Ca	6.69	6.75	7.16	7.61								
Ti	6.71	6.78	6.82	6.91								
Cr.....	6.71	6.80	6.87	6.91	6.98	7.05						
Mn.....	6.68	6.79	6.87	6.92	6.99	7.03	7.12					
Fe.....	6.60	6.80	6.89	6.96	7.02	7.09	7.15	7.26	7.55	8.00		
Co	6.43		6.79		6.97	7.02	7.09	7.14	7.23			
Ni.....	6.41	6.47	6.55	6.78		6.98	7.03	7.10	7.16	7.27	7.68	8.00
Zn				6.62				7.09	7.15	7.21	7.29	

NOTE.—Temperature of the maximum ion abundance for the ions included in the CHIANTI database. Ion fractions come from Arnaud & Raymond (1992) for the Fe ions, Landini & Monsignori Fossi (1991) for the minor ions, Arnaud & Rothenflug (1985) for the other ions.

TABLE 5

CHIANTI XUV Line List

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
…	1.2540	Ni XXVII	$1s^2\ ^1S_0$ - $1s\ 5p\ ^1P_1$	1.1e+03	
…	1.2830	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	2.5e+03	
…	1.2934	Ni XXVIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	1.2e+03	
…	1.3500	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	7.6e+03	
…	1.3520	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 3p\ ^3P_1$	1.3e+03	
…	1.3917	Fe XXVI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	7.5e+03	
…	1.3919	Fe XXVI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	3.8e+03	
…	1.4249	Fe XXVI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	1.5e+04	
…	1.4253	Fe XXVI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	7.4e+03	
…	1.4610	Fe XXV	$1s^2\ ^1S_0$–$1s\ 5p\ ^3P_1$	3.5e+03	
…	1.4610	Fe XXV	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	2.6e+04	
…	1.4950	Fe XXV	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	5.7e+04	
…	1.4950	Fe XXV	$1s^2\ ^1S_0$–$1s\ 4p\ ^3P_1$	7.8e+03	
…	1.5023	Fe XXVI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	4.6e+04	
…	1.5035	Fe XXVI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	2.3e+04	
…	1.5303	Ni XXVIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	7.7e+03	
…	1.5358	Ni XXVIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	3.8e+03	
…	1.5415	Ni XXVII d	$1s\ 2p\ ^1P_1$–$2p\ 2p\ ^1D_2$	1.1e+03	
1.567	1.5730	Fe XXV	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	1.7e+05	19
	1.5750	Fe XXV	$1s^2\ ^1S_0$–$1s\ 3p\ ^3P_1$	2.6e+04	
1.587	1.5880	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	5.2e+04	19
…	1.5923	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$	7.7e+03	
…	1.5935	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^1P)\ ^2P_{1/2}$	1.2e+03	
…	1.5965	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	1.0e+04	
…	1.5970	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$	5.6e+03	
…	1.5977	Ni XXVI d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 2p\ ^2P_{3/2}$	1.1e+03	
…	1.5984	Ni XXVI d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{3/2}$	2.3e+03	
…	1.5996	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{1/2}$	1.5e+03	
…	1.6009	Ni XXVI d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$	3.5e+03	
…	1.6036	Ni XXVII	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	1.0e+04	
1.778	1.7780	Fe XXVI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	3.0e+05	20
…	1.7795	Fe XXV d	$1s\ 3p\ ^1P_1$–$2p\ 3p\ ^1D_2$	1.3e+04	
1.783	1.7833	Fe XXVI	$1s\ ^2S_{1/2}$–$2s\ ^2S_{1/2}$	1.0e+04	20
	1.7834	Fe XXVI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	1.5e+05	
…	1.7872	Fe XXV d	$1s\ 2s\ ^1S_0$–$2s\ 2p\ ^1P_1$	1.9e+04	
…	1.7873	Fe XXV d	$1s\ 2p\ ^3P_2$–$2p^2\ ^1D_2$	1.2e+04	
1.792	1.7920	Fe XXV d	$1s\ 2p\ ^1P_1$–$2p^2\ ^1D_2$ (*J*)	3.7e+04	20
	1.7926	Fe XXV d	$1s\ 2p\ ^3P_2$–$2p^2\ ^3P_2$	1.4e+04	
1.8283					13
1.8309					13
1.8344					13
1.8389					13
1.8424					13
1.8499	1.8500	Fe XXV	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (*w*)	1.2e+06	13
…	1.8517	Fe XXIV d	$1s^2\ 3d\ ^2D_{5/2}$–$1s\ 2p\ (^1P)\ 3d\ ^2F_{7/2}$	1.3e+04	
…	1.8525	Fe XXIV d	$1s^2\ 3p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{3/2}$	1.4e+04	
…	1.8532	Fe XXIV d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{5/2}$	1.8e+04	
1.8552	1.8554	Fe XXV	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$ (*x*)	1.6e+05	13
1.8568	1.8565	Fe XXIV d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 3p\ ^2D_{5/2}$	6.2e+03	13
	1.8566	Fe XXIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2S_{1/2}$ (*m*)	7.2e+03	
	1.8571	Fe XXIV d	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s2p\ (^1P)\ ^2P_{1/2}$ (*t*)	1.6e+04	
	1.8572	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^1P)\ ^2P_{1/2}$ (*t*)	1.7e+04	
1.8595	1.8595	Fe XXV	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (*y*)	2.1e+05	13
	1.8604	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$	9.4e+04	
1.8610	1.8604	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$ (*q*)	9.4e+04	13
1.8631	1.8622	Fe XXIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 2p\ ^2P_{3/2}$ (*a*)	2.0e+04	13
	1.8630	Fe XXIV d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{3/2}$ (*k*)	4.9e+04	
	1.8635	Fe XXIV d	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s2p\ (^3P)\ ^2P_{1/2}$ (*r*)	7.9e+03	
	1.8637	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{1/2}$ (*r*)	2.6e+04	
1.8660	1.8659	Fe XXIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$ (*j*)	7.3e+04	13
1.8680	1.8676	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^4P_{5/2}$	1.5e+04	13
	1.8682	Fe XXV	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (*z*)	2.3e+05	
1.8704	1.8721	Fe XXIII d	$2s\ 2p\ ^3P_1$–$1s\ 2s\ 2p^2\ ^3D_1$	1.1e+04	13

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
1.8732	1.8724	Fe XXIII d	$2s\ 2p\ ^3P_0$–$1s\ 2s\ (^4P)\ 2p^2\ ^3P_1$	7.3e+03	13
	1.8727	Fe XXIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 2p\ ^4P_{5/2}$ (*e*)	1.2e+04	
	1.8728	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^4P_{1/2}$ (*v*)	5.1e+03	
	1.8730	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^4P_{3/2}$ (*u*)	1.2e+04	
	1.8731	Fe XXIII d	$2s\ 2p\ ^3P_1$–$1s\ 2s\ 2p^2\ ^3D_2$	3.0e+04	
	1.8734	Fe XXIII d	$2s\ 2p\ ^3P_2$–$1s\ 2s\ (^4P)\ 2p^2\ ^3P_2$	9.6e+03	
1.8754	1.8754	Fe XXIII d	$2s\ 2p\ ^3P_2$–$1s\ 2s\ 2p^2\ ^3D_3$	4.1e+04	13
1.8779	1.8771	Fe XXIII d	$2s\ 2p\ ^1P_1$–$1s\ 2s\ 2p^2\ ^1D_2$	9.1e+03	13
	1.8786	Fe XXIII d	$2s^2\ ^1S_0$–$1s\ 2s^2 2p\ ^3P_1$	2.7e+03	
1.8794	1.8795	Fe XXII d	$2s^2\ 2p\ ^2P_{3/2}$–$1s\ 2s^2\ 2p^2\ ^2S_{1/2}$	1.1e+03	13
1.8824	1.8822	Fe XXII d	$2s^2\ 2p\ ^2P_{1/2}$–$1s\ 2s^2\ 2p^2\ ^2D_{3/2}$	3.4e+03	13
1.8851	1.8849	Fe XXII d	$2s^2\ 2p\ ^2P_{3/2}$–$1s\ 2s^2\ 2p^2\ ^2D_{5/2}$	4.5e+03	13
1.8867	1.8870	Fe XXIII d	$2s\ 2p\ ^3P_2$–$1s\ 2s\ 2p^2\ ^5P_3$	1.8e+03	13
1.8916	1.8924	Fe XXIV d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2s^2\ ^2S_{1/2}$ (*p*)	2.1e+03	13
1.8942	1.8944	Fe XXI d	$2p^2\ ^3P_0$–$1s\ 2s^2 2p^3\ ^3D_1$	2.4e+03	13
1.8966	1.8965	Fe XXI d	$2p^2\ ^3P_1$–$1s\ 2s^2 2p^3\ ^3D_2$	3.2e+03	13
	1.8969	Fe XXIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2s^2\ ^2S_{1/2}$ (*o*)	2.2e+03	
	1.8969	Fe XXI d	$2p^2\ ^3P_2$–$1s\ 2s^2 2p^3\ ^3D_3$	1.2e+03	
1.9051	1.9051	Fe XX	$1s^2\ 2s^2\ 2p^3\ ^4S_{3/2}$–$1s\ 2s^2\ 2p^4\ ^4P_{5/2}$	…	13
1.9075	1.9075	Fe XX	$1s^2\ 2s^2\ 2p^3\ ^2P_{3/2}$–$1s\ 2s^2\ 2p^4\ ^2P_{3/2}$	…	13
1.9360	1.9360	Fe Kα_1		…	13
1.9400	1.9400	Fe Kα_2		…	13
2.706	2.7054	Ca XIX	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	9.9e+03	19
3.0185	3.0185	Ca XX	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	3.6e+04	13
3.0239	3.0239	Ca XX	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	1.8e+04	13
3.0485	3.0486	Ca XIX d	$1s\ 2p\ ^1P_1$–$2p^2\ ^1D_2$ (*j*)	3.8e+03	13
3.16	3.1502	Ar XVIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	1.9e+04	19
	3.1514	Ar XVIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	9.6e+03	
3.1769	3.1772	Ca XIX	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (*w*)	6.9e+04	13
3.1822	3.1820	Ca XVIII d	$1s^2\ 3p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{3/2}$	9.1e+02	13
	3.1829	Ca XVIII d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{5/2}$	1.4e+03	
3.1889	3.1891	Ca XIX	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$ (*x*)	7.9e+03	13
3.1925	3.1927	Ca XIX	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (*y*)	9.0e+03	13
3.2003	3.1961	Ca XVIII	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$ (*q*)	2.4e+03	13
	3.1996	Ar XVII	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	9.5e+03	
3.2033	3.2038	Ca XVIII d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 2p\ ^2P_{3/2}$ (*a*)	7.2e+02	13
3.2066	3.2064	Ca XVIII d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{3/2}$ (*k*)	2.5e+03	13
3.2111	3.2102	Ca XVIII d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$ (*j*)	3.4e+03	13
	3.2111	Ca XIX	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (*z*)	1.8e+04	
3.371	3.3654	Ar XVII	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	3.0e+04	19
3.698	3.6958	S XVI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	7.4e+03	19
	3.6960	S XVI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	3.7e+03	
3.733	3.7311	Ar XVIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	1.4e+05	19
	3.7365	Ar XVIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	6.8e+04	
…	3.7554	Ar XVII d	$1s\ 2s\ ^1S_0$–$2s\ 2p\ ^1P_1$	4.0e+03	
…	3.7720	Ar XVII d	$1s\ 2p\ ^1P_1$–$2p\ 2p\ ^1D_2$	1.2e+04	
3.786	3.7843	S XVI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	1.7e+04	19
	3.7847	S XVI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	8.4e+03	
3.949	3.9488	Ar XVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	2.1e+05	19
3.969	3.9656	Ar XVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$	2.0e+04	19
	3.9691	Ar XVII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	2.6e+04	
…	3.9978	S XV	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	9.0e+03	
4.004	3.9908	S XVI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	5.1e+04	19
	3.9919	S XVI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	2.6e+04	
	3.9939	Ar XVII	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	6.2e+04	
4.104	4.0885	S XV	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	2.0e+04	19
4.299	4.2991	S XV	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	6.4e+04	19
4.729	4.7274	S XVI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	3.7e+05	19
	4.7328	S XVI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	1.8e+05	
4.769	4.7611	S XV d	$1s\ 2s\ ^1S_0$–$2s\ 2p\ ^1P_1$	8.5e+03	19
…	4.7848	S XV d	$1s\ 2p\ ^1P_1$–$2p\ 2p\ ^1D_2$	2.7e+04	
4.834	4.8310	Si XIV	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	1.5e+04	19
	4.8312	Si XIV	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	7.6e+03	
4.948	4.9467	Si XIV	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	3.4e+04	19
	4.9472	Si XIV	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	1.7e+04	
5.039	5.0387	S XV	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (*w*)	4.5e+05	18, 19

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
5.050	5.0484	S XIV d	$1s^2\ 3p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{3/2}$	4.4e+03	18
	5.0495	S XIV d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{5/2}$	6.8e+03	
5.066	5.0631	S XV	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$ (*x*)	2.8e+04	18, 19
	5.0665	S XV	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (*y*)	5.4e+04	
5.105	5.1015	S XV	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (*z*)	1.5e+05	18, 19
	5.1025	S XIV d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$ (*j*)	1.0e+04	
5.220	5.2168	Si XIV	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	1.1e+05	18, 19
	5.2179	Si XIV	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	5.3e+04	
5.228	5.2230	Si XIII	$1s^2\ ^1S_0$–$1s\ 6p\ ^1P_1$	…	18
5.238					18
5.285	5.2856	Si XIII	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	1.2e+04	18, 19
5.407	5.4046	Si XIII	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	2.8e+04	18, 19
5.682	5.6807	Si XIII	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	8.9e+04	16, 17, 18, 19
5.816	5.8157	Si XII d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2p\ (^3P)\ 3p\ ^2D_{3/2}$	1.4e+03	19
	5.8163	Si XII d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 3p\ ^2D_{5/2}$	2.9e+03	
6.049	6.0525	Al XIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	7.1e+03	19
	6.0537	Al XIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	3.6e+03	
…	6.1720	Si XIII d	$1s\ 3d\ ^1D_2$–$2p\ 3d\ ^1F_3$	1.0e+04	
6.180	6.1804	Si XIV	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	7.8e+05	17, 18, 19
6.187	6.1858	Si XIV	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	3.9e+05	17, 18
…	6.1993	Si XIII d	$1s\ 3d\ ^3D_3$–$2p\ 3d\ ^3F_4$	5.6e+03	
6.212					18
6.224	6.2296	Si XIII d	$1s\ 2s\ ^1S_0$–$2s\ 2p\ ^1P_1$	1.2e+04	19
…	6.2446	Si XIII d	$1s\ 2s\ ^3S_1$–$2s\ 2p\ ^3P_2$	8.2e+03	
…	6.2482	Si XIII d	$1s\ 2s\ ^3S_1$–$2s\ 2p\ ^3P_1$	5.0e+03	
6.261					17, 18
6.266	6.2650	Si XIII d	$1s\ 2p\ ^1P_1$–$2p\ 2p\ ^1D_2$	3.8e+04	17, 18, 19
6.319					18
6.324					18
6.333					18
6.364					18
6.402					18
6.420					18
6.470					18
6.485					18
6.581	6.5800	Mg XII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	9.3e+03	18
	6.5802	Mg XII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	4.6e+03	
…	6.6350	Al XII	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	4.5e+03	
6.647	6.6480	Si XIII	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (*w*)	6.1e+05	16, 17, 18
…	6.6539	Si XII d	$1s^2\ 3d\ ^2D_{3/2}$–$1s\ 2p\ (^1P)\ 3d\ ^2F_{5/2}$	5.2e+03	
6.659	6.6554	Si XII d	$1s^2\ 3d\ ^2D_{5/2}$–$1s\ 2p\ (^1P)\ 3d\ ^2F_{7/2}$	8.2e+03	16
	6.6627	Si XII d	$1s^2\ 3p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{3/2}$	5.4e+03	
	6.6638	Si XII d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{5/2}$	7.8e+03	
6.685	6.6851	Si XIII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$ (*x*)	3.0e+03	17, 18
6.688	6.6883	Si XIII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (*y*)	4.4e+04	17, 18
6.692	6.6891	Si XII d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^3P)\ 3p\ ^2D_{5/2}$	8.3e+02	16
6.720	6.7180	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$ (*q*)	5.4e+03	16
	6.7200	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{1/2}$ (*r*)	2.1e+03	
6.740	6.7377	Mg XII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	2.1e+04	16, 17, 18
	6.7382	Mg XII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	1.0e+04	
	6.7404	Si XIII	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (*z*)	1.4e+05	
…	6.7432	Si XII d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$	8.1e+03	
…	6.8111	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{3/2}$	6.6e+03	
…	6.8208	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{1/2}$	3.5e+03	
6.950					17, 18
7.102	7.1058	Mg XII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	6.3e+04	17, 18
7.105	7.1069	Mg XII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	3.2e+04	17, 18
7.170	7.1690	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 5p\ ^2P_{1/2}$	1.8e+04	16, 17, 18
	7.1690	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 5p\ ^2P_{3/2}$	3.4e+04	
	7.1709	Al XIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	5.1e+04	
	7.1763	Al XIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	2.5e+04	
7.310	7.3100	Mg XI	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	4.0e+03	17, 18
7.368	7.3698	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 5d\ ^2D_{3/2}$	1.6e+04	12
7.377					12
7.387	7.3910	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 5s\ ^2S_{1/2}$	6.5e+03	12
7.438	7.4381	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 5d\ ^2D_{5/2}$	1.4e+03	12
	7.4403	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 5d\ ^2D_{3/2}$	2.9e+03	

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
7.454	7.4620	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 5s\ ^2S_{1/2}$	1.4e+04	12
7.473	7.4730	Mg XI	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	9.0e+03	12, 17, 18
	7.4720	Fe XXIII	$2s^2\ ^1S_0$–$2s\ 5p\ ^1P_1$	…	
7.477					12, 16
7.498					12
7.561					12
7.685					16
7.710					17, 18
7.757	7.7570	Al XII	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (w)	3.0e+04	17, 18
7.774					17, 18
7.808	7.8070	Al XII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (y)	3.2e+03	16, 17, 18
7.850	7.8510	Mg XI	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	2.8e+04	11, 12, 17, 18
7.872	7.8721	Al XII	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (z)	1.2e+04	11, 12, 17, 18
7.902					11, 12
7.919					11, 12
7.936					12
7.952					16
7.987	7.9828	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{3/2}$	1.0e+05	11, 12, 16
7.997	7.9930	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{1/2}$	5.4e+04	11, 12, 16
8.069					17, 18
8.091					11, 12
8.141					16
8.153					12, 16, 18
8.159					12, 18
8.168					12
8.204					12
8.232	8.2311	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4d\ ^2D_{3/2}$	5.2e+04	11, 12, 16
8.270					12
8.285	8.2836	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4s\ ^2S_{1/2}$	2.2e+04	12
8.304	8.3030	Fe XXIII	$2s^2\ ^1S_0$–$2s\ 4p\ ^1P_1$	1.2e+05	11, 12, 13, 16
8.316	8.3158	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{5/2}$	9.3e+04	11, 12, 13, 16, 17
	8.3193	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{3/2}$	1.0e+04	
8.325					14
8.376	8.3729	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	4.6e+04	16
8.419	8.4192	Mg XII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	4.4e+05	17, 18
8.424	8.4246	Mg XII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	2.2e+05	17, 18
8.500	8.4956	Mg XI d	$1s\ 2s\ ^1S_0$–$2s\ 2p\ ^1P_1$	3.8e+03	18
8.531	8.5290	Fe XXIII	$2s\ 2p\ ^3P_0$–$2s\ 4d\ ^3D_1$	5.4e+03	12
8.552	8.5500	Fe XXIII	$2s\ 2p\ ^3P_1$–$2s\ 4d\ ^3D_2$	1.1e+04	11, 12, 17, 18
	8.5513	Mg XI d	$1s\ 2p\ ^1P_1$–$2p\ 2p\ ^1D_2$	1.2e+04	
8.573					11, 12, 16, 17, 18
8.617	8.6140	Fe XXIII	$2s\ 2p\ ^3P_2$–$2s\ 4d\ ^3D_3$	2.0e+04	11, 12, 16
	8.6180	Fe XXIII	$2s\ 2p\ ^3P_2$–$2s\ 4d\ ^3D_2$	3.7e+03	
8.644					11, 12
8.660					11, 12
8.715					11, 12
8.722					11, 12
8.734					11, 12
8.753					12
8.814	8.8140	Fe XXIII	$2s\ 2p\ ^1P_1$–$2s\ 4d\ ^1D_2$	1.3e+05	11, 12, 16
8.823					14
8.848					11, 12, 18
8.906	8.9060	Fe XXIII	$2s\ 2p\ ^1P_1$–$2s\ 4s\ ^1S_0$	5.0e+04	11, 12
8.919					11, 12, 16
8.933					12
8.976	8.9770	Fe XXII	$2s\ 2p^2\ ^2D_{5/2}$–$2s\ 2p\ (^3P)\ 4d\ ^2F_{7/2}$	…	11, 12, 14, 16, 18
8.993					12
9.007					11, 12
9.068	9.0613	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	4.0e+04	11, 12
9.073					11, 12, 14, 16, 17, 18
9.114	9.1050	Ni XXVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	2.1e+04	11, 12, 16
9.136					11, 12
9.150					18
9.170	9.1690	Mg XI	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$ (w)	1.9e+05	12, 14, 16, 17, 18
9.173					18
9.181	9.1796	Mg X d	$1s^2\ 3d\ ^2D_{3/2}$–$1s\ 2p\ (^1P)\ 3d\ ^2F_{5/2}$	1.1e+03	16, 17, 18
	9.1811	Mg X d	$1s^2\ 3d\ ^2D_{5/2}$–$1s\ 2p\ (^1P)\ 3d\ ^2F_{7/2}$	1.6e+03	

TABLE 5—*Continued*

$\lambda_{\rm solar}$ (Å)	λ (Å)	Ion	Transition	Int	Refs
9.189	9.1927	Mg x d	$1s^2\ 3p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{3/2}$	8.9e+02	12, 17, 18
9.194	9.1938	Mg x d	$1s^2\ 3p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 3p\ ^2D_{5/2}$	1.4e+03	12, 16, 17, 18
9.202					12
9.215					18
9.224					12
9.233	9.2282	Mg xi	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_2$ (x)	2.4e+03	12, 14, 16, 17, 18
	9.2312	Mg xi	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$ (y)	2.1e+04	
9.241					16
9.252					12
9.276					12
9.284	9.2840	Mg x	$1s^2\ 2s\ ^2S_{1/2}$–$1s\ 2s\ 2p\ (^3P)\ ^2P_{3/2}$ (q)	8.3e+02	17
9.290					12, 16, 18
9.298					18
9.314	9.3143	Mg xi	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$ (z)	7.1e+04	12, 16, 17, 18
9.319	9.3161	Mg x d	$1s^2\ 2p\ ^2P_{1/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{3/2}$ (k)	7.50e+02	12, 14, 16, 17, 18
	9.3206	Mg x d	$1s^2\ 2p\ ^2P_{3/2}$–$1s\ 2p\ (^1P)\ 2p\ ^2D_{5/2}$ (j)	1.2e+03	
…	9.3400	Ni xxv	$2s^2\ ^1S_0$–$2s\ 3p\ ^1P_1$	2.0e+04	
9.361	9.3620	Ne x	$1s\ ^2S_{1/2}$–$6p\ ^2P_{3/2}$	…	11, 12, 18
9.383					11, 12
9.391	9.3898	Ni xxvi	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	2.7e+04	11, 12, 16, 17, 18
	9.3900	Ni xxv	$2s^2\ ^1S_0$–$2s\ 3p\ ^3P_1$	1.0e+04	
9.416	9.4150	Fe xxiii	$2p^2\ ^1S_0$–$2s\ 4p\ ^1P_1$	3.9e+03	11, 12
9.455	9.4510	Fe xxi	$2p^2\ ^3P_1$–$2p\ 4d\ ^3D_2$	2.5e+05	12
9.476					11, 12
9.481	9.4807	Ne x	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	1.5e+04	11, 12, 14, 16, 17, 18
	9.4809	Ne x	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	7.4e+03	
9.525	9.5353	Ni xxvi	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	4.8e+04	16
9.542					11, 12
9.548	9.5490	Ni xxvi	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	5.3e+03	11, 12
9.554	9.5590	Fe xxi	$2p^2\ ^3P_2$–$2p\ 4d\ ^3D_1$	3.7e+03	16
…	9.5668	Ni xxvi	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.2e+04	
9.586	9.5810	Fe xxi	$2p^2\ ^1D_2$–$2p\ 4d\ ^3F_3$	1.6e+04	11, 12, 16
9.632	9.6330	Ni xxv	$2s\ 2p\ ^3P_1$–$2s\ 3d\ ^3D_2$	2.0e+03	11, 12
9.656					16
9.663					11, 12
9.690	9.6880	Fe xix	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 5d\ ^3D_3$	…	11, 12
9.710	9.7080	Ne x	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	3.3e+04	11, 12, 17, 18
9.711	9.7085	Ne x	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	1.6e+04	11, 12, 16, 17, 18
9.726	9.7321	Ni xxvi	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	2.5e+04	12
9.795	9.7990	Fe xix	$2p^4\ ^3P_1$–$2p^3\ (^2D)\ 5d\ ^3D_2$	…	11, 12
9.807	9.8090	Cr xxii	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4d\ ^2D_{3/2}$	1.0e+03	11, 12, 16
9.847	9.8420	Fe xix	$2p^4\ ^3P_2$–$2p^3\ (^4S)\ 5d\ ^3D_3$	…	11, 12
9.858					16
9.896					12
9.902					16
9.940					12
9.945					12
9.973	9.9680	Ni xxv	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	4.1e+04	11, 12
9.988	9.9910	Fe xx	$2p^3\ ^4S_{3/2}$–$2p^2\ (^3P)\ 4d\ ^4P_{3/2}$	…	14
9.998	10.0015	Fe xxv	$1s\ 2s\ ^3S_1$–$1s\ 3p\ ^3P_2$	8.9e+03	11, 12, 16
10.021	10.0232	Na xi	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	1.9e+04	12, 14
	10.0286	Na xi	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	9.3e+03	
10.069					16
10.134	10.1340	Fe xvii	$2s^2\ 2p^6\ ^1S_0$–$2s\ 2p^6\ 5p\ ^3P_1$	…	14, 16
10.250	10.2385	Ne x	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	7.4e+04	16
	10.2396	Ne x	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	3.7e+04	
10.328	10.3220	Ni xxv	$2s\ 2p\ ^1P_1$–$2s\ 3s\ ^1S_0$	2.4e+04	16
10.359					16
…	10.3690	Fe xxv	$1s\ 2p\ ^3P_1$–$1s\ 3s\ ^3S_1$	1.9e+03	
10.382	10.3860	Fe xvii	$2s^2\ 2p^6\ ^1S_0$–$2s^2\ 2p^5\ (^2P_{1/2})\ 7d\ ^1P_1$	…	14
10.502	10.4985	Fe xxv	$1s\ 2p\ ^3P_2$–$1s\ 3s\ ^3S_1$	1.6e+03	16
	10.5060	Fe xvii	$2s^2\ 2p^6\ ^1S_0$–$2s^2\ 2p^5\ (^2P_{3/2})\ 7d\ ^3D_1$	…	
10.530	10.5330	Co xxv	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.1e+03	16
10.564	10.5597	Fe xxiii	$2s^2\ ^1S_0$–$2p\ 3s\ ^1P_1$	6.5e+03	17, 18
	10.5640	Fe xix	$2p^4\ ^3P_1$–$2p^3\ (^2P)\ 4d\ ^3D_2$	…	
10.579	10.5859	Fe xxv	$1s\ 2p\ ^1P_1$–$1s\ 3s\ ^1S_0$	6.3e+03	16, 17, 18
10.620	10.6190	Fe xxiv	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	6.0e+05	17, 18

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
10.636	10.6350	Fe XIX	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 4d\ ^3S_1$	…	14, 17, 18
10.647	10.6440	Fe XIX	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 4d\ ^3P_2$	…	16
10.654	10.6550	Fe XVII	$2s^2\ 2p^6\ ^1S_0$–$2s^2\ 2p^5\ (^2P_{1/2})\ 6d\ ^1P_1$	…	16, 17
10.662	10.6630	Fe XXIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	3.2e+05	14, 17, 18
10.684	10.6840	Fe XIX	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 4d\ ^3F_3$	…	17, 18
10.718					18
10.738	10.7350	Fe XIX	$2p^4\ ^3P_1$–$2p^3\ (^2D)\ 4d\ ^3S_1$	…	18
10.769	10.7643	Ne IX	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	2.7e+03	16, 17, 18
	10.7700	Fe XIX	$2p^4\ ^3P_1$–$2p^3\ (^2D)\ 4d\ ^3D_2$	…	
	10.7700	Fe XVII	$2s^2\ 2p^6\ ^1S_0$–$2s^2\ 2p^5\ (^2P_{3/2})\ 6d\ ^3D_1$	…	
10.778					14, 18
10.791					14
10.818	10.8130	Fe XIX	$2p^4\ ^3P_2$–$2p^3\ (^4S)\ 4d\ ^3D_3$	…	16, 17, 18
10.827	10.8240	Fe XIX	$2p^4\ ^1D_2$–$2p^3\ (^2D)\ 4d\ ^1D_2$	…	18
10.857					18
10.933	10.9351	Fe XXIII	$2s\ 2p\ ^3P_1$–$2p\ 3p\ ^3D_2$	4.7e+03	17, 18
	10.9330	Fe XIX	$2p^4\ ^3P_1$–$2p^3\ (^4S)\ 4d\ ^3D_2$	…	
10.980	10.9806	Fe XXIII	$2s^2\ ^1S_0$–$2s\ 3p\ ^1P_1$	5.7e+05	16, 17, 18
10.996	11.0003	Ne IX	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	6.0e+03	14, 16, 17, 18
	11.0027	Na X	$2s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	6.2e+03	
11.014	11.0181	Fe XXIII	$2s^2\ ^1S_0$–$2s\ 3p\ ^3P_1$	2.8e+05	17, 18
11.026	11.0229	Fe XVII	$2p^6\ ^1S_0$–$2s\ 2p^6\ 4p\ ^1P_1$	8.8e+03	14, 16, 17, 18
	11.0290	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	4.0e+05	
11.041	11.0229	Fe XVII	$2p^6\ ^1S_0$–$2s\ 2p^6\ 4p\ ^3P_1$	1.1e+03	18
11.132	11.1320	Fe XVII	$2s^2\ 2p^6\ ^1S_0$–$2s^2\ 2p^5\ (^2P_{1/2})\ 5d\ ^1P_1$	…	14, 16, 17, 18
11.147					18
11.172	11.1709	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	7.1e+05	14, 16, 17, 18
11.189	11.1879	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	7.8e+04	14, 16, 17, 18
11.253	11.2530	Fe XVII	$2s^2\ 2p^6$–$2s^2\ 2p^5\ (^2P_{3/2})\ 5d$	…	14, 16, 17, 18
	11.2530	Fe XVIII	$2p^5\ ^2P_{1/2}$–$2p^4\ (^1S)\ 4d\ ^2D_{3/2}$	…	
11.269	11.2606	Fe XXIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.8e+05	14
11.292	11.2984	Fe XXIII	$2s\ 2p\ ^3P_0$–$2s\ 3d\ ^3D_1$	2.6e+04	17, 18
11.311					17, 18
11.325	11.3252	Fe XXIII	$2s\ 2p\ ^3P_1$–$2s\ 3d\ ^3D_2$	4.7e+04	17, 18
11.334	11.3380	Fe XXIII	$2s\ 2p\ ^3P_1$–$2s\ 3d\ ^3D_1$	1.9e+04	14, 16
11.420	11.4200	Fe XVIII	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 4d\ ^2F_{5/2}$	…	17, 18
11.429	11.4263	Fe XXIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	3.7e+05	16
11.443	11.4414	Fe XXIII	$2s\ 2p\ ^3P_2$–$2s\ 3d\ ^3D_3$	7.8e+04	14, 16, 17, 18
	11.4417	Fe XXII	$2s^2\ 2p\ ^2P_{1/2}$–$2s\ 2p\ (^3P)\ 3p\ ^2D_{3/2}$	2.1e+05	
11.458	11.4580	Fe XVIII	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 4d\ ^4F_{5/2}$	…	17, 18
11.480					17, 18
11.495	11.5101	Fe XXII	$2s^2\ 2p\ ^2P_{1/2}$–$2s\ 2p\ (^3P)\ 3p\ ^2P_{3/2}$	7.6e+04	14, 16
11.527	11.5196	Fe XXIII	$2p^2\ ^3P_0$–$2p\ 3d\ ^3D_1$	1.4e+04	1, 17, 18
	11.5260	Fe XVIII	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 4d\ ^2D_{5/2}$	…	
11.537					14
11.545	11.5470	Ne IX	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	1.8e+04	16, 17, 18
11.580					18
11.594					18
11.640	11.6457	Fe XXIII	$2s\ 2p\ ^3P_1$–$2s\ 3s\ ^1S_0$	1.3e+04	18
…	11.6690	Fe XXII	$2s^2\ 2p\ ^2P_{3/2}$–$2s\ 2p\ (^3P)\ 3p\ ^2P_{3/2}$	2.7e+04	
11.740	11.7363	Fe XXIII	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	1.1e+06	14, 16, 17, 18
11.771	11.7675	Fe XXII	$2s^2\ 2p\ ^2P_{1/2}$–$2s^2\ (^1S)\ 3d\ ^2D_{3/2}$	1.1e+06	14, 16, 17, 18
11.825	11.7955	Fe XXII	$1s^2\ 2s\ 2p^2\ ^4P_{3/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2D_{5/2}$	9.3e+04	
	11.7960	Fe XXII	$1s^2\ 2s\ 2p^2\ ^4P_{1/2}$–$2s\ 2p\ (^3P)\ 3d\ ^4D_{3/2}$	1.2e+04	
	11.8207	Fe XXII	$1s^2\ 2s\ 2p^2\ ^4P_{5/2}$–$2s\ 2p\ (^3P)\ 3d\ ^4D_{5/2}$	2.4e+04	17, 18
11.836	11.8320	Ni XX	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{5/2}$	1.7e+04	14, 16
	11.8410	Ni XX	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2P_{3/2}$	9.0e+03	
11.864	11.8734	Fe XXIII	$2s\ 2p\ ^3P_2$–$2s\ 3s\ ^3S_1$	2.3e+04	17, 18
11.885	11.8852	Fe XXII	$1s^2\ 2s\ 2p^2\ ^4P_{3/2}$–$2s\ 2p\ (^3P)\ 3d\ ^4P_{5/2}$	4.9e+04	16, 18
…	11.8971	Fe XXIII	$2p^2\ ^1S_0$–$2p\ 3d\ ^1P_1$	4.1e+04	
11.926	11.9208	Fe XXII	$2s^2\ 2p\ ^2P_{3/2}$–$2s^2\ (^1S)\ 3d\ ^2D_{5/2}$	7.1e+04	14
11.934	11.9336	Fe XXII	$2s^2\ 2p\ ^2P_{3/2}$–$2s^2\ (^1S)\ 3d\ ^2D_{3/2}$	2.1e+05	16, 17, 18
11.972	11.9750	Fe XXII	$1s^2\ 2s\ 2p^2\ ^4P_{5/2}$–$2s\ 2p\ (^3P)\ 3d\ ^4F_{7/2}$	1.6e+04	14, 16, 17, 18
…	12.0097	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2S_{1/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2P_{3/2}$	1.8e+04	
…	12.0578	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{3/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2F_{5/2}$	6.0e+04	
…	12.0764	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2S_{1/2}$–$2s\ 2p\ (^1P)\ 3d\ ^2D_{3/2}$	1.4e+04	
…	12.0778	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2P_{3/2}$–$2s\ 2p\ (^1P)\ 3d\ ^2D_{5/2}$	2.9e+04	

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
...	12.0912	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{5/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2F_{5/2}$	5.2e+04	
...	12.0981	Fe XXIII	$2p^2\ ^1D_2$–$2p\ 3s\ ^1P_1$	1.9e+04	
12.122	12.1227	Fe XVII	$2s^2\ 2p^6$–$2s^2\ 2p^5\ (^2P_{1/2})\ 4d$	1.5e+05	1, 17, 18
12.128	12.1321	Ne X	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	7.4e+05	14, 17, 18
	12.1375	Ne X	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	3.7e+05	
12.153	12.1760	Fe XXIII	$2s\ 2p\ ^1P_1$–$2s\ 3s\ ^1S_0$	6.2e+05	17, 18
12.199	12.1926	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2P_{1/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2P_{3/2}$	2.9e+04	14, 17, 18
	12.1931	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{3/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2D_{5/2}$	1.4e+05	
...	12.2273	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{5/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2D_{5/2}$	2.1e+04	
12.264	12.2639	Fe XVII	$2s^2\ 2p^6$–$2s^2\ 2p^5\ (^2P_{3/2})\ 4d$	1.3e+05	17, 18
12.285	12.2850	Fe XXI	$2p^2\ ^3P_0$–$2s^2\ 2p\ 3d\ ^3D_1$	1.4e+06	17, 18
12.399	12.3980	Fe XXI	$2p^2\ ^3P_1$–$2s^2\ 2p\ 3d\ ^3D_1$	2.5e+05	14, 17, 18
12.408					17, 18
12.429	12.4351	Ni XIX	$2p^6\ ^1S_0$–$2p^5\ 3d\ ^1P_1$	2.3e+04	14, 17, 18
12.460	12.4620	Fe XXI	$2p^2\ ^3P_1$–$2s^2\ 2p\ 3d\ ^1D_2$	4.4e+04	17, 18
	12.4650	Fe XXI	$2p^2\ ^3P_2$–$2s^2\ 2p\ 3d\ ^3D_1$	1.5e+04	
12.501					14, 17, 18
12.522	12.5250	Fe XXI	$2p^2\ ^3P_2$–$2s^2\ 2p\ 3d\ ^3F_3$	5.6e+04	17, 18
12.550					17, 18
12.566					17, 18
12.581	12.5855	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2P_{3/2}$–$2s\ 2p\ (^3P)\ 3d\ ^2D_{5/2}$	1.3e+04	14, 17, 18
	12.5880	Fe XXI	$2p^2\ ^3P_2$–$2s^2\ 2p\ 3d\ ^3F_2$	2.4e+04	
12.599					17, 18
12.622	12.6230	Cr XXII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	8.4e+03	18
	12.6230	Fe XXI	$2p^2\ ^1S_0$–$2s^2\ 2p\ 3d\ ^1P_1$	1.1e+04	
12.638					18
12.654	12.6538	Fe XXIII	$2p^2\ ^1D_2$–$2s\ 3p\ ^1P_1$	8.9e+03	14, 17, 18
	12.6560	Ni XIX	$2p^6\ ^1S_0$–$2p^5\ 3d\ ^3D_1$	8.0e+03	
12.682	12.6780	Fe XVII	$2s^2\ 2p^6$–$2s^2\ 2p^5\ (^2P_{3/2})\ 4s$	3.6e+03	17, 18
...	12.7330	Fe XXI	$2p^2\ ^1D_2$–$2s^2\ 2p\ 3d\ ^1D_2$	1.4e+04	
12.754					14, 18
12.765					18
12.775					18
12.788	12.7930	Fe XXI	$2p^2\ ^1D_2$–$2s^2\ 2p\ 3d\ ^3F_2$	1.3e+04	18
12.812	12.8173	Fe XX	$2s^2\ 2p^3\ ^4S_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^4P_{3/2}$	5.6e+05	1, 14, 17, 18
	12.8173	Fe XX	$2s^2\ 2p^3\ ^4S_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^4P_{5/2}$	5.2e+05	
12.829					14, 17, 18
12.847					17, 18
12.888	12.8884	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^1D)\ 3d\ ^2F_{7/2}$	1.1e+04	18
12.904					17, 18
12.912					14
12.925	12.9251	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^1D)\ 3d\ ^2D_{5/2}$	4.0e+03	14, 17, 18
	12.9280	Fe XXI	$2p^2\ ^3P_0$–$2s^2\ 2p\ 3s\ ^3P_1$	1.0e+04	
12.940					18
12.952					14, 17, 18
12.966					14, 17, 18
12.983	12.9796	Fe XX	$2s^2\ 2p^3\ ^2D_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^2D_{5/2}$	4.4e+04	17, 18
12.998					18
13.009					18
13.019					14, 17, 18
13.053	13.0431	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^2D_{5/2}$	1.3e+04	17, 18
	13.0530	Fe XXI	$2p^2\ ^3P_1$–$2s^2\ 2p\ 3s\ ^3P_1$	6.0e+03	
	13.0553	Fe XX	$2s^2\ 2p^3\ ^2P_{3/2}$–$2s^2\ 2p^2\ (^1D)\ 3d\ ^2F_{5/2}$	5.0e+03	
13.060	13.0553	Fe XX	$2s^2\ 2p^3\ ^2P_{3/2}$–$2s^2\ 2p^2\ (^1D)\ 3d\ ^2F_{5/2}$	5.0e+03	14
13.091	13.0823	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^2F_{7/2}$	2.3e+04	14, 17, 18
	13.1132	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^4P_{3/2}$	2.2e+04	
	13.1132	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^4P_{5/2}$	7.6e+04	
	13.1280	Fe XXI	$2p^2\ ^3P_2$–$2s^2\ 2p\ 3s\ ^3P_1$	1.9e+04	
13.143	13.1371	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{5/2}$–$2s\ 2\ (^1S)\ 3p\ ^2P_{3/2}$	2.9e+04	14, 17, 18
	13.1500	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2D_{3/2}$–$2s^2\ (^1S)\ 3p\ ^2P_{1/2}$	1.2e+05	
13.162	13.1601	Fe XX	$2s^2\ 2p^3\ ^2P_{1/2}$–$2s^2\ 2p^2\ (^3P)\ 3d\ ^2D_{3/2}$	1.1e+04	14, 17, 18
13.232					14
13.253					17, 18
13.265	13.2640	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2P^*)\ 3d\ ^3D_3$	1.0e+04	14, 17, 18
13.279					14, 17, 18
...	13.2920	Cr XXII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	1.2e+04	
13.308	13.3080	Ni XX	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^4P_{5/2}$	6.9e+03	17, 18

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
13.323	13.3190	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2s\ 2p^5\ (^3P^*)\ 3p\ ^2D_{5/2}$	6.6e+03	14, 17, 18
	13.3190	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2s\ 2p^5\ (^3P^*)\ 3p\ ^2P_{1/2}$	6.5e+03	
13.356	13.3480	Fe XIX	$2s^2\ 2p^4\ ^3P_0$–$2p^3\ (^2P^*)\ 3d\ ^3P_1$	1.2e+04	17, 18
	13.3551	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2s\ 2p^5\ (^3P^*)\ 3p\ ^2P_{3/2}$	9.8e+03	
	13.3551	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2S_{1/2}$–$2s^2\ (^1S)\ 3p\ ^2P_{1/2}$	2.4e+04	
13.377	13.3740	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2s\ 2p^5\ (^3P^*)\ 3p\ ^4P_{5/2}$	1.0e+04	14, 17, 18
13.404	13.3969	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2s\ 2p^5\ (^3P^*)\ 3p\ ^4D_{3/2}$	5.2e+03	
13.426	13.4250	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^1F_3$	1.9e+04	17, 18
13.448	13.4470	Ne IX	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	1.2e+05	1, 14, 17, 18
13.464	13.4640	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^3S_1$	5.5e+04	
13.507	13.5040	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^3D_2$	9.7e+03	1, 17, 18
13.519	13.5210	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^3D_3$	2.0e+05	14, 17, 18
13.551	13.5515	Fe XXII	$1s^2\ 2s\ 2p^2\ ^2P_{3/2}$–$2s\ 2\ (^1S)\ 3p\ ^2P_{3/2}$	8.2e+03	1, 17, 18
	13.5529	Ne IX	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	1.2e+04	
	13.5550	Cr XXII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	5.8e+03	
	13.5680	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^3P_2$	8.7e+04	
13.631					17, 18
13.649	13.6470	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3d\ ^3F_3$	1.2e+04	14, 17, 18
13.672	13.6700	Fe XIX	$2s^2\ 2p^4\ ^3P_1$–$2p^3\ (^2D^*)\ 3d\ ^3D_2$	2.2e+04	14, 17, 18
13.700	13.6987	Ne IX	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	4.3e+04	1, 14, 17, 18
13.719					17, 18
13.738	13.7360	Fe XIX	$2s^2\ 2p^4\ ^1D_2$–$2p^3\ (^2D^*)\ 3d\ ^1F_3$	1.7e+04	17, 18
	13.7361	Fe XX	$2s^2\ 2p^3\ ^4S_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^4P_{5/2}$	9.7e+04	
13.778	13.7791	Fe XIX	$2s^2\ 2p^4\ ^1D_2$–$2p^3\ (^2D^*)\ 3d\ ^3S_1$	1.0e+04	1, 17, 18
	13.7790	Ni XIX	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^1P_1$	7.7e+03	
13.795	13.7950	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^4S^*)\ 3d\ ^3D_3$	6.0e+04	14, 17, 18
13.827	13.8181	Fe XX	$2s^2\ 2p^3\ ^4S_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^4P_{3/2}$	5.0e+04	1, 17, 18
	13.8231	Fe XVII	$2p^6\ ^1S_0$–$2s\ 2p^6\ 3p\ ^1P_1$	7.3e+04	
13.844					14, 17, 18
13.891	13.8910	Fe XVII	$2p^6\ ^1S_0$–$2s\ 2p^6\ 3p\ ^3P_1$	1.1e+04	1, 17, 18
13.934					17, 18
13.948	13.9451	Fe XX	$2s^2\ 2p^3\ ^4S_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^4P_{1/2}$	3.9e+04	1, 14
	13.9540	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1S)\ 3d\ ^2D_{5/2}$	2.2e+04	
13.958	13.9540	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1S)\ 3d\ ^2D_{5/2}$	2.2e+04	17, 18
13.967	13.9690	Fe XIX	$2s^2\ 2p^4\ ^1D_2$–$2p^3\ (^2D^*)\ 3d\ ^3F_3$	3.3e+03	14
14.017	14.0096	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^2P_{3/2}$	2.1e+04	17, 18
	14.0146	Fe XX	$2s^2\ 2p^3\ ^2D_{3/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^2P_{1/2}$	1.7e+04	
14.028					1, 14
14.041	14.0430	Ni XIX	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^3P_1$	1.3e+04	14, 17, 18
14.078	14.0766	Fe XX	$2s^2\ 2p^3\ ^2D_{5/2}$–$2s^2\ 2p^2\ (^3P)\ 3s\ ^4P_{5/2}$	2.4e+04	1, 14, 17, 18
	14.0770	Ni XIX	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^3P_2$	7.9e+03	
14.124	14.1209	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^1S)\ 3d\ ^2D_{3/2}$	2.2e+03	17, 18
	14.1359	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2P_{1/2}$	6.2e+03	
14.152	14.1519	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{3/2}$	1.4e+04	1, 17, 18
14.208	14.2030	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{5/2}$	4.0e+05	1, 14, 17, 18
	14.2078	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2P_{3/2}$	2.1e+05	
14.262	14.2566	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2S_{1/2}$	7.3e+04	1, 14, 17, 18
14.311					17, 18
14.345	14.3439	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^1D)\ 3d\ ^2P_{1/2}$	2.6e+04	1, 17, 18
14.360	14.3604	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{3/2}$	4.1e+04	17, 18
14.373	14.3740	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^2D_{5/2}$	1.4e+05	1, 17, 18
14.388					14
14.422	14.4179	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^1D)\ 3d\ ^2P_{3/2}$	3.2e+04	14, 17, 18
14.456	14.4530	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^2D_{3/2}$	8.8e+03	1, 17, 18
...	14.4682	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^1D)\ 3d\ ^2S_{1/2}$	1.4e+04	
14.482	14.4850	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^4F_{5/2}$	2.6e+04	14, 17, 18
14.496					14
14.535	14.5341	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^2F_{5/2}$	9.8e+04	1, 17, 18
14.552	14.5510	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^4P_{3/2}$	4.8e+04	1, 14, 17, 18
14.585	14.5811	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3d\ ^4P_{1/2}$	2.2e+04	17, 18
14.611	14.6098	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^3P)\ 3d\ ^2P_{3/2}$	7.0e+03	17, 18
14.669	14.6670	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^2D^*)\ 3s\ ^3D_3$	6.6e+03	1, 14, 17, 18
	14.6705	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^3P)\ 3d\ ^2D_{3/2}$	7.3e+03	
14.703					17, 18
14.739					14, 17, 18
14.747					1, 14
14.760					14, 17, 18

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
14.818	14.8205	O VIII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	3.4e+04	1, 14, 17, 18
	14.8207	O VIII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	1.7e+04	
14.873	14.8681	Fe XVIII	$2s^2\ 2p^5\ ^2P_{1/2}$–$2p^4\ (^3P)\ 3d\ ^4D_{1/2}$	4.2e+03	14, 17, 18
14.908					17, 18
14.919					14
14.930					17, 18
14.962					14
14.974	14.9700	Fe XIX	$2s^2\ 2p^4\ ^3P_2$–$2p^3\ (^4S^*)\ 3s\ ^3S_1$	4.4e+03	17, 18
15.012	15.0150	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3d\ ^1P_1$	1.1e+06	1, 14, 17, 18
15.040					17, 18
15.080					14, 17, 18
15.114					17, 18
15.177	15.1760	O VIII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	7.6e+04	1, 14, 17, 18
	15.1765	O VIII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	3.8e+04	
15.208					1, 17, 18
15.265	15.2621	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3d\ ^3D_1$	2.6e+05	1, 14, 17, 18
15.279					1, 18
15.289					17
15.374					1, 14, 17, 18
15.410					17, 18
15.432					17, 18
15.454	15.4500	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3d\ ^3P_1$	3.4e+04	1, 14, 15, 17, 18
15.495					1, 14, 15, 17, 18
15.516					14, 15, 17, 18
15.626	15.6250	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3s\ ^2D_{5/2}$	4.0e+04	1, 14, 15, 17, 18
15.679					17, 18
15.766					1, 14, 15, 17, 18
15.829	15.8281	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^4P_{3/2}$	3.3e+04	1, 14, 15, 17, 18
15.870					1, 14, 15, 17, 18
16.003	16.0050	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^2P_{3/2}$	5.8e+04	1, 14, 15, 17, 18
	16.0055	O VIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	2.2e+05	
	16.0067	O VIII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	1.1e+05	
16.017					17, 18
16.074	16.0720	Fe XVIII	$2s^2\ 2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^4P_{5/2}$	1.4e+05	1, 14, 15, 17, 18
16.108					1, 14, 15, 17, 18
16.167	16.1670	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2s\ 2p^5\ (^3P)\ 3s\ ^2P_{3/2}$	8.9e+04	1, 14, 15, 17, 18
16.238	16.2380	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3p\ ^3P_2$	5.8e+03	1, 17, 18
16.249					15
16.274					14, 15, 17, 18
16.312	16.2950	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2s\ 2p^5\ (^3P)\ 3s\ ^4P_{3/2}$	2.4e+04	14, 15, 17, 18
16.344	16.3360	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3p\ ^3D_2$	8.3e+03	1, 14, 15, 17, 18, 20
16.618					17, 18
16.631					15, 18
16.774	16.7760	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^3P_1$	3.7e+05	1, 14, 15, 17, 18, 20
16.821					17, 18
16.956					14
17.051	17.0510	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^1P_1$	4.4e+05	1, 14, 15, 17, 18, 20
17.098	17.0960	Fe XVII	$2p^6\ ^1S_0$–$2p^5\ 3s\ ^3P_2$	2.5e+05	1, 15, 17, 18, 20
17.205	17.2010	Fe XVI	$2p^6\ 3p$–$2p^5\ 3s\ 3p$	…	15, 17, 18
17.318					15
17.367	17.3500	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^1S)\ 3p\ ^2P_{3/2}$	5.2e+03	15
	17.3700	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{5/2}$	…	
17.390	17.3960	O VII	$1s^2\ ^1S_0$–$1s\ 5p\ ^1P_1$	2.1e+03	15, 18
17.499	17.5010	Fe XVI	$2p^6\ 3p$–$2p^5\ 3s\ 3p$	…	15, 17, 18
	17.5010	Fe XVI	$2p^6\ 3d$–$2p^5\ 3s\ 3d$	…	
17.622	17.6220	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^1D)\ 3p\ ^2P_{3/2}$	2.4e+05	1, 14, 15, 17, 18
17.684					15
17.765	17.7680	O VII	$1s^2\ ^1S_0$–$1s\ 4p\ ^1P_1$	4.7e+03	14, 15
17.798	17.8040	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^1D)\ 3p\ ^2D_{3/2}$	6.4e+03	15
…	18.0290	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^3P)\ 3p\ ^2D_{3/2}$	6.9e+03	
18.090	18.0900	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^3P)\ 3p\ ^4S_{3/2}$	4.8e+03	15
18.202	18.2020	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^3P)\ 3p\ ^4D_{3/2}$	1.6e+04	15
	18.2020	Fe XVIII	$2s\ 2p^6\ ^2S_{1/2}$–$2p^4\ (^3P)\ 3p\ ^2P_{3/2}$	1.3e+04	
18.360					1
18.401					15
18.499	18.4970	Cr XV	$2p^6\ ^1S_0$–$2p^5\ (^2P_{1/2})\ 3d\ ^1P_1$	…	1, 15, 18
18.565					15

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
18.627	18.6270	O VII	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	1.4e+04	1, 14, 15, 17, 18
18.689	18.6909	Ca XVIII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	2.0e+04	15
18.733	18.7319	Ca XVIII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	1.0e+04	15
18.783	18.7860	Ar XVI	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	4.4e+03	15
18.928	18.9320	O VII d	$1s\ 3d\ ^1D_2$–$2p\ 3d\ ^1F_3$	2.4e+03	
18.970	18.9671	O VIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	1.4e+06	1, 14, 15, 17, 18
	18.9725	O VIII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	7.2e+05	
19.059	19.0610	O VII d	$1s\ 3d\ ^3D_3$–$2p\ 3d\ ^3F_4$	2.3e+03	17, 18
	19.0640	O VII d	$1s\ 3d\ ^3D_2$–$2p\ 3d\ ^3F_3$	1.5e+03	
	19.0660	O VII d	$1s\ 3d\ ^3D_1$–$2p\ 3d\ ^3F_2$	1.1e+03	
19.260	19.2550	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3s\ ^2D_{5/2}$	…	1, 15
19.300	19.3060	O VII d	$1s\ 2s\ ^3S_1$–$2s\ 2p\ ^3P_2$	1.9e+03	15
	19.3100	O VII d	$1s\ 2s\ ^3S_1$–$2s\ 2p\ ^3P_1$	1.1e+03	
19.354	19.3612	N VII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	2.3e+03	17, 18
	19.3614	N VII	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	1.1e+03	
19.403	19.3930	O VII d	$1s\ 2p\ ^1P_1$–$2p^2\ ^1D_2$	4.3e+03	17, 18
19.511	19.5110	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^1D)\ 3s\ ^2D_{3/2}$	…	15
19.532	19.5380	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^2P_{3/2}$	…	15
19.564	19.5580	Ca XVII	$2s^2\ ^1S_0$–$2s\ 3p\ ^1P_1$	2.3e+03	15
19.583	19.5825	Ca XVII	$2s^2\ ^1S_0$–$2s\ 3p\ ^3P_1$	1.8e+03	17, 18
19.640	19.6420	Ca XVIII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	1.4e+04	15
19.715	19.7140	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^2P_{1/2}$	…	15
19.788	19.7892	Ca XVIII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	2.5e+04	15
19.808	19.8009	Ca XVIII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	2.7e+03	15
	19.8070	Cr XVI	$2p^5\ ^2P_{3/2}$–$2p^4\ (^3P)\ 3s\ ^4P_{5/2}$	…	
…	19.8257	N VII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	5.0e+03	
…	19.8261	N VII	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	2.5e+03	
19.916					15
…	20.0530	Ca XVIII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	6.2e+03	
20.126	20.1219	Ar XVIII	$2p\ ^2P_{1/2}$–$3s\ ^2S_{1/2}$	3.3e+02	15
…	20.2190	Ca XVIII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.3e+04	
20.288	20.2804	Ar XVIII	$2p\ ^2P_{3/2}$–$3s\ ^2S_{1/2}$	6.4e+02	15
20.318	20.3400	Ca XVII	$2s\ 2p\ ^3P_1\ 2s\ 3d\ ^3D_2$	2.7e+02	15, 18
20.434	20.4370	Ca XVII	$2s\ 2p\ ^3P_2$–$2s\ 3d\ ^3D_3$	5.0e+02	15
20.862	20.8610	K XVII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	4.9e+02	1, 15, 18
	20.8630	Cr XV	$2p^6\ ^1S_0$–$2p^5\ (^2P_{1/2})\ 3s\ ^1P_1$	…	
20.906	20.9095	N VII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	1.4e+04	1, 15
	20.9106	N VII	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	7.3e+03	
21.153	21.1530	Cr XV	$2p^6\ ^1S_0$–$2p^5\ (^2P_{3/2})\ 3s\ ^3P_1$	…	1, 15
21.202	21.1980	Ca XVII	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	5.9e+03	1, 15
…	21.3830	Fe XXIV	$1s^2\ 3s\ ^2S_{1/2}$–$1s^2\ 5p\ ^2P_{3/2}$	3.2e+03	
…	21.3830	Fe XXIV	$1s^2\ 3s\ ^2S_{1/2}$–$1s^2\ 5p\ ^2P_{1/2}$	1.7e+03	
21.447	21.4500	Ca XVI	$2p\ ^2P_{1/2}$–$2s^2\ 3d\ ^2D_{3/2}$	2.9e+03	1, 15
21.603	21.6020	O VII	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	9.1e+04	1, 14, 15, 18
21.802	21.8070	O VII	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	5.8e+03	1, 14, 15
21.850	21.8200	Fe XXIV	$1s^2\ 3p\ ^2P_{1/2}$–$1s^2\ 5d\ ^2D_{3/2}$	1.7e+03	18
22.025	22.0200	K XVII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	3.5e+02	15
	22.0595	Si XIV	$2s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	4.8e+02	
22.100	22.1012	O VII	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	3.5e+04	1, 15, 18
…	22.1140	Ca XVII	$2s\ 2p\ ^1P_1$–$2s\ 3s\ ^1S_0$	3.7e+03	
…	22.1980	Fe XXIV	$1s^2\ 3p\ ^2P_{3/2}$–$1s^2\ 5s\ ^2S_{1/2}$	2.9e+03	
22.722	22.7250	Ca XV	$2p^2\ ^3P_0$–$2p\ 3d\ ^3D_1$	2.3e+03	1, 15
22.778	22.8210	Ca XV	$2p^2\ ^3P_2$–$2p\ 3d\ ^3D_1$	5.5e+02	15
…	23.0050	S XIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{3/2}$	7.4e+03	
…	23.0150	S XIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{1/2}$	3.9e+03	
…	23.5460	Ar XVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	3.2e+04	
…	23.5900	Ar XVI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	1.6e+04	
24.09	24.1100	Ca XIV	$2p^3\ ^4S_{3/2}$–$2p^2\ (^3P)\ 3d\ ^4P_{5/2}$	…	1
24.13					1
…	24.2000	S XIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4d\ ^2D_{3/2}$	3.8e+03	
…	24.2850	S XIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{5/2}$	6.9e+03	
24.38					1
…	24.4180	S XIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4s\ ^2S_{1/2}$	1.6e+03	
…	24.5080	S XIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	3.2e+03	
24.53	24.5199	Si XIII	$1s\ 2s\ ^3S_1$–$1s\ 5p\ ^3P_1$	3.2e+02	1
24.68	24.6955	Si XIV	$2p\ ^2P_{1/2}$–$4d\ ^2D_{3/2}$	5.2e+02	1
	24.6987	Si XIV	$2s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	9.8e+02	

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
24.78	24.7792	N VII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	9.0e+04	1
	24.7846	N VII	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	4.5e+04	
24.86	24.8540	Ar XVI	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	2.4e+04	1
…	24.9910	Ar XVI	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	4.2e+04	
…	25.0130	Ar XVI	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	4.6e+03	
…	25.5160	Ar XVI	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	9.9e+03	
…	25.6840	Ar XVI	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	2.0e+04	
26.03	26.0000	Ca XIII	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 3d\ ^3P_2$	…	1
	26.0330	Ca XIII	$2p^4\ ^3P_2$–$2p^3\ (^2D)\ 3d\ ^3D_3$	…	
26.22	26.2190	Ca XIII	$2p^4\ ^3P_1$–$2p^3\ (^2D)\ 3d\ ^3D_2$	…	1
26.36	26.3572	C VI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	3.6e+03	1
	26.3574	C VI	$1s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	1.8e+03	
26.59					1
26.64					1
26.71	26.7190	Ca XIII	$2p^4\ ^3P_2$–$2p^3\ (^4S)\ 3d\ ^3D_3$	…	1
27.01	26.9896	C VI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	7.7e+03	1
	26.9901	C VI	$1s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	3.8e+03	
27.15					1
…	27.4100	Ar XV	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	5.3e+03	
…	27.4700	Ar XIV	$2p\ ^2P_{1/2}$–$2s^2\ 3d\ ^2D_{3/2}$	2.7e+03	
…	27.5304	S XV	$1s\ 2s\ ^3S_1$–$1s\ 3p\ ^3P_2$	3.7e+03	
27.56	27.5598	S XV	$1s\ 2s\ ^3S_1$–$1s\ 3p\ ^3P_1$	1.4e+03	1
27.60	27.6080	Ca XII	$2p^5\ ^2P_{1/2}$–$2p^4\ (^1S)\ 3d\ ^2D_{3/2}$	…	1
27.65	27.6420	Ar XIV	$2p\ ^2P_{3/2}$–$2s^2\ 3d\ ^2D_{3/2}$	5.4e+02	1
27.98	27.9730	Ca XII	$2p^5\ ^2P_{3/2}$–$2p^4\ (^1S)\ 3d\ ^2D_{5/2}$	…	1
28.13	28.1310	Ca XII	$2p^5\ ^2P_{1/2}$–$2p^4\ (^1D)\ 3d\ ^2D_{3/2}$	…	1
28.40	28.3860	Ar XV	$2s\ 2p\ ^1P_1$–$2s\ 3s\ ^1S_0$	3.4e+03	1
28.46	28.4652	C VI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	2.2e+04	1
	28.4663	C VI	$1s\ ^2S_{1/2}$–$3p\ ^2P_{1/2}$	1.1e+04	
28.56					1
28.78	28.7870	N VI	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	3.7e+03	1
28.91	28.9084	Si XIII	$1s\ 2p\ ^1P_1$–$1s\ 4d\ ^1D_2$	3.5e+02	1
	28.9382	S XV	$1s\ 2p\ ^3P_1$–$1s\ 3s\ ^3S_1$	3.6e+02	
29.07	29.0840	N VI	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	2.6e+02	1
29.53	29.5343	N VI	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	1.7e+03	1
	29.5438	S XV	$1s\ 2p\ ^1P_1$–$1s\ 3s\ ^1S_0$	2.3e+03	
29.65	29.5740	Si XII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 5s\ ^2S_{1/2}$	7.4e+02	
	29.6450	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 5s\ ^2S_{1/2}$	4.4e+02	1
29.99					1
30.09					1
30.45	30.4270	S XIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	4.2e+04	1
	30.4690	S XIV	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	2.2e+04	
30.56					1
…	30.7260	Fe XXIV	$1s^2\ 3s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{3/2}$	7.4e+03	
…	30.8780	Fe XXIV	$1s^2\ 3s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{1/2}$	4.0e+03	
31.01	31.0120	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{3/2}$	5.2e+03	1
	31.0230	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 4p\ ^2P_{1/2}$	2.7e+03	
…	31.6160	Fe XXIV	$1s^2\ 3p\ ^2P_{1/2}$–$1s^2\ 4d\ ^2D_{3/2}$	4.4e+03	
31.74	31.7460	Fe XXIII	$2s\ 3s\ ^3S_1$–$2s\ 4p\ ^1P_1$	6.9e+02	1
31.77					1
31.83					1
31.94	31.9590	Fe XXIV	$1s^2\ 3p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{5/2}$	7.9e+03	1
32.01	32.0100	Fe XXIV	$1s^2\ 3p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{3/2}$	8.7e+02	1
32.19	32.1910	S XIII	$2s^2\ ^1S_0$–$2s\ 3p\ ^3P_1$	1.0e+03	1
32.24	32.2420	S XIII	$2s^2\ ^1S_0$–$2s\ 3p\ ^1P_1$	1.9e+03	1
32.29					1
32.41	32.4040	Fe XXIV	$1s^2\ 3p\ ^2P_{1/2}$–$1s^2\ 4s\ ^2S_{1/2}$	3.8e+03	1
	32.4160	S XIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	2.8e+04	
32.50	32.4890	Fe XXIII	$2s\ 3s\ ^1S_0$–$2s\ 4p\ ^1P_1$	4.5e+03	1
32.55	32.5600	S XIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	4.9e+04	1
…	32.5750	S XIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	5.5e+03	
32.66	32.6520	Fe XVI	$3p\ ^2P_{3/2}$–$7d\ ^2D_{5/2}$	…	1
…	32.8190	Fe XXIV	$1s^2\ 3p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	8.1e+03	
32.97	32.9730	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{5/2}$	4.9e+03	1
33.22	33.2220	Si XII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 4s\ ^2S_{1/2}$	1.1e+03	1

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
33.30	33.3023	Si XIV	$2p\ ^2P_{1/2}$–$3d\ ^2D_{3/2}$	1.4e+03	1
	33.3081	Si XIV	$2s\ ^2S_{1/2}$–$3p\ ^2P_{3/2}$	2.2e+03	
	33.3130	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	2.2e+03	
33.38	33.3810	S XIV	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.2e+04	1
...	33.4340	Fe XXIII	$2s\ 3p\ ^1P_1$–$2s\ 4d\ ^1D_2$	9.1e+03	
33.50	33.5069	Si XIV	$2p\ ^2P_{3/2}$–$3s\ ^2S_{1/2}$	3.5e+03	1
33.54	33.5490	S XIV	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	2.5e+04	1
33.73	33.7342	C VI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{3/2}$	1.4e+05	1
	33.7396	C VI	$1s\ ^2S_{1/2}$–$2p\ ^2P_{1/2}$	6.8e+04	
33.96	33.9510	S XIII	$2s\ 2p\ ^3P_2$–$2s\ 3d\ ^3D_3$	4.0e+02	1
34.86	34.8570	Fe XVI	$3p\ ^2P_{1/2}$–$6d\ ^2D_{3/2}$	...	1
34.99	34.9730	C V	$1s^2\ ^1S_0$–$1s\ 3p\ ^1P_1$	4.9e+02	1
35.10	35.0950	P XIII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	3.9e+02	1
	35.1060	Fe XVI	$3p\ ^2P_{3/2}$–$6d\ ^2D_{5/2}$	...	
35.21					1
35.36	35.3680	Fe XVI	$3d\ ^2D_{5/2}$–$8f\ ^2F_{7/2}$	...	1
	35.3530	Si XI	$2s\ 2p\ ^3P_0$–$2s\ 4d\ ^3D_1$	...	
	35.3830	Si XI	$2s\ 2p\ ^3P_1$–$2s\ 4d\ ^3D_2$	...	
35.46	35.4460	Si XI	$2s\ 2p\ ^3P_2$–$2s\ 4d\ ^3D_3$	...	1
35.57					1
35.67	35.6670	S XIII	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	4.1e+03	1
35.73	35.7100	Fe XVI	$3p\ ^2P_{1/2}$–$6s\ ^2S_{1/2}$	...	1
35.80					1
36.01	36.0100	Fe XVI	$3p\ ^2P_{3/2}$–$6s\ ^2S_{1/2}$	...	1
36.12					1
36.40	36.3980	S XII	$2s^2\ 2p\ ^2P_{1/2}$–$2s^2\ 3d\ ^2D_{3/2}$	1.5e+03	1
...	36.4333	Si XIII	$1s\ 2s\ ^3S_1$–$1s\ 3p\ ^3P_2$	5.1e+03	
36.52					1
36.56	36.5640	S XII	$2s^2\ 2p\ ^2P_{3/2}$–$2s^2\ 3d\ ^2D_{5/2}$	7.0e+02	1
	36.5730	S XII	$2s^2\ 2p\ ^2P_{3/2}$–$2s^2\ 3d\ ^2D_{3/2}$	3.0e+02	
36.75	36.7490	Fe XVI	$3s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	2.9e+03	1
36.80	36.8030	Fe XVI	$3s\ ^2S_{1/2}$–$5p\ ^2P_{1/2}$	1.6e+03	1
36.89					1
37.35					1
37.42					1
37.60	37.5980	S XIII	$2s\ 2p\ ^1P_1$–$2s\ 3s\ ^1S_0$	2.6e+03	1
37.71	37.7060	P XIII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	5.1e+02	1
	37.7150	S XII	$2s\ 2p^2\ ^2D_{3/2}$–$2s\ 2p\ (^3P^*)\ 3d\ ^2F_{5/2}$	3.7e+02	
...	39.4147	Si XIII	$1s\ 2p\ ^1P_1$–$1s\ 3s\ ^1S_0$	3.1e+03	
39.66	39.6680	Mg X	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 5p\ ^2P_{3/2}$	2.9e+02	1
39.75					1
39.83	39.8270	Fe XVI	$3p\ ^2P_{1/2}$–$5d\ ^2D_{3/2}$	2.7e+03	1
39.89					1
39.94					1
40.14	40.1530	Fe XVI	$3p\ ^2P_{3/2}$–$5d\ ^2D_{5/2}$	4.8e+03	1
40.19	40.1990	Fe XVI	$3d\ ^2D_{3/2}$–$6f\ ^2F_{5/2}$	...	1
40.27	40.2680	C V	$1s^2\ ^1S_0$–$1s\ 2p\ ^1P_1$	3.2e+03	1
40.72	40.7307	C V	$1s^2\ ^1S_0$–$1s\ 2p\ ^3P_1$	2.4e+02	1
40.86					1
40.91	40.9110	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	3.0e+04	1
40.95	40.9510	Si XII	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	1.5e+04	1, 7
41.01					1
41.13					7
41.22					1
41.47	41.4721	C V	$1s^2\ ^1S_0$–$1s\ 2s\ ^3S_1$	1.9e+03	1, 7
41.94	41.9320	Fe XVI	$3p\ ^2P_{1/2}$–$5s\ ^2S_{1/2}$	3.0e+03	1, 7
42.27	42.3040	Fe XVI	$3p\ ^2P_{3/2}$–$5s\ ^2S_{1/2}$	6.2e+03	1
42.55	42.5430	S X	$2p^3\ ^4S_{3/2}$–$2p^2\ (^3P)\ 3d\ ^4P_{5/2}$	...	1, 7
42.61					1
43.31	43.3149	Ne X	$2s\ ^2S_{1/2}$–$5p\ ^2P_{3/2}$	4.6e+02	1, 7
43.65					1
43.76	43.7630	Si XI	$2s^2\ ^1S_0$–$2s\ 3p\ ^1P_1$	1.0e+03	1, 7
43.80					1
44.02	44.0190	Si XII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3d\ ^2D_{3/2}$	1.9e+04	1
44.17	44.1650	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{5/2}$	3.4e+04	1, 7
	44.1780	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	3.8e+03	
44.20	44.1780	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3d\ ^2D_{3/2}$	3.8e+03	1

TABLE 5—*Continued*

λ_{solar} (Å)	λ (Å)	Ion	Transition	Int	Refs
44.36					1
44.55					7
44.86					7
45.06					1, 7
45.51	45.5210	Si XII	$1s^2\ 2p\ ^2P_{1/2}$–$1s^2\ 3s\ ^2S_{1/2}$	8.4e+03	1, 7
45.68	45.6910	Si XII	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 3s\ ^2S_{1/2}$	1.7e+04	1, 7
45.73					1
45.76					1
46.00					7
46.18					1
46.33	46.2980	Si XI	$2s\ 2p\ ^3P_1$–$2s\ 3d\ ^3D_2$	1.3e+02	1, 7
	46.3140	Al XII	$1s\ 2p\ ^1P_1$–$1s\ 3s\ ^1S_0$	1.5e+02	
46.40	46.3990	Si XI	$2s\ 2p\ ^3P_2$–$2s\ 3d\ ^3D_3$	3.6e+02	1
46.66	46.6610	Fe XVI	$3d\ ^2D_{3/2}$–$5f\ ^2F_{5/2}$	2.6e+03	1
46.72	46.7180	Fe XVI	$3d\ ^2D_{5/2}$–$5f\ ^2F_{7/2}$	3.6e+03	1, 7
47.33	47.3100	Mg X	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4d\ ^2D_{5/2}$	7.7e+02	1, 7
47.60					7
47.67	47.6630	Ni XVII	$3s\ 3p\ ^1P_1$–$3s\ 4d\ ^1D_2$	...	1
47.79	47.7720	Ni XVI	$3s^2\ 3p\ ^2P_{3/2}$–$3s^2\ 4d\ ^2D_{5/2}$	...	1
47.85	47.8790	Mg X	$1s^2\ 2p\ ^2P_{3/2}$–$1s^2\ 4s\ ^2S_{1/2}$	3.4e+02	7
48.25					1
48.29	48.2970	Al XI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{3/2}$	9.5e+02	1
48.33	48.3380	Al XI	$1s^2\ 2s\ ^2S_{1/2}$–$1s^2\ 3p\ ^2P_{1/2}$	4.8e+02	1
48.51	48.5010	Ne X	$2p\ ^2P_{1/2}$–$4d\ ^2D_{3/2}$	5.0e+02	7
	48.5048	Ne X	$2s\ ^2S_{1/2}$–$4p\ ^2P_{3/2}$	9.4e+02	
	48.5113	Ne X	$2p\ ^2P_{1/2}$–$4s\ ^2S_{1/2}$	4.2e+02	
	48.5156	Ne X	$2s\ ^2S_{1/2}$–$4p\ ^2P_{1/2}$	4.7e+02	
48.97	48.9530	Fe XVI	$3d\ ^2D_{5/2}$–$5p\ ^2P_{3/2}$	5.1e+02	1
	48.9790	Fe XVI	$3d\ ^2D_{3/2}$–$5p\ ^2P_{1/2}$	3.0e+02	
49.18					1
49.22	49.2220	Si XI	$2s\ 2p\ ^1P_1$–$2s\ 3d\ ^1D_2$	1.9e+03	1, 7
49.31					1
49.49					1
49.64					1
49.71					1
49.76					1
49.81					1
49.88					1

References.—(1) Acton et al. 1985; (7) Widing & Sandlin 1968; (11) Fawcett et al. 1987; (12) the list of Fawcett et al. 1987 revised by Phillips et al. 1999; (13) Feldman, Doschek, & Kreplin 1980; (14) McKenzie et al. 1980; (15) McKenzie & Landecker 1982; (16) McKenzie et al. 1985; (17) Phillips et al. 1982; (18) Phillips et al. 1999; (19) Doschek 1972; (20) Pike et al. 1996.

given by

$$\frac{C_d}{A_a} = \frac{h^3}{2(2\pi mkT)^{3/2}} \frac{g_u}{g_l} \exp\left(-\Delta E/kT\right), \quad (1)$$

where h is the Planck constant, m the electron mass, k the Boltzmann constant, T the temperature in kelvins, g_u the statistical weight of the upper level, g_l the statistical weight of the lower level, ΔE the difference in energy of the two levels. For electron collisional excitation of an ion, the collisional rate coefficient C is related to the Maxwellian-averaged collision strength $\Upsilon(T)$ by

$$C = \left(\frac{2\pi}{k}\right)^{1/2} \frac{\hbar^2}{m^{3/2}}\, T^{1/2}\, \frac{\Upsilon(T)}{g_l} \exp\left(-\Delta E/kT\right). \quad (2)$$

By comparing equations (1) and (2), one can derive a Maxwellian-averaged collision strength Υ_d for the excitation of autoionizing states

$$\Upsilon_d = \frac{g_u h A_a}{2kT}. \quad (3)$$

CHIANTI has employed the scaling laws of Burgess & Tully (1992) which suggest how the collision strength should scale with energy or temperature for four kinds of transitions. Equation (3) has led us to adopt a new type of transition where the collision strength scales with the inverse of the temperature and we have used this to scale the dielectronic excitation rates.

For implementation within CHIANTI, we assume that dielectronic excitation of levels above the ionization potential proceeds independently from the direct excitation of levels below the ionization potential. This is accomplished by employing different model ions for the two kinds of transitions. As an example, for the calculation of line intensities from helium-like Fe XXV, we calculate the steady-state level populations of the Fe XXV ion as described in Paper I. The rate at which these levels are populated is proportional to the relative population of the Fe XXV ion. For the lithium-like dielectronic satellites of Fe XXV, we calculate the steady-state level populations of Fe XXIV but use the dielectronic excitation rates as the only means of populating the upper levels. The rate at which these levels are populated is pro-

portional to the relative population of the Fe XXV ion. For the direct excitation of the Fe XXIV levels, including the levels produced by inner shell excitation, we use the Fe XXIV ion including all the direct excitation rates and the rate is proportional to the relative population of the Fe XXIV ion.

In practice, two sets of files are used to calculate those line intensities due to direct excitation and those due to dielectronic excitation. In the case of C V, the lines due to direct excitation use the CHIANTI standard set of three ASCII files with the prefix "c_5." For those lines created by dielectronic excitation, the three files have the prefix "c_4*d*."

3. NEW ATOMIC DATA IN THE CHIANTI DATABASE

3.1. *The Hydrogen Isoelectronic Sequence*

3.1.1. C VI, Ne X, Si XIV, Ca XX, Fe XXVI

For the hydrogen isoelectronic sequence, the 25 fine-structure levels of the 1*s*, 2*l*, 3*l*, 4*l*, and 5*l* configurations have been included. Observed energies are taken from the National Institute of Science and Technology (NIST) Atomic Spectra Database (Fuhr et al. 1999).[2] For oscillator strengths of allowed lines, the hydrogenic values of Wiese, Smith, & Glennon (1966) have been used. Radiative transition probabilities (*A*-values) have been calculated from the hydrogenic oscillator strengths and the observed energy level separations. For $Z \leq 26$, no significant differences with respect to the relativistic calculations of Pal'chikov (1998) are found. The magnetic dipole and two photon decay rates from the first excited level $2s\ ^2S_{1/2}$ are taken from Parpia & Johnson (1972).

In a series of papers, Aggarwal & Kingston have performed R-matrix calculations of collisions strengths of the hydrogenic ions for transitions among the 15 *LS nl* levels with $n = 1$–5. The collision strengths for C VI are from Aggarwal & Kingston (1991a), for Ne X from Aggarwal & Kingston (1991b), for Si XIV from Aggarwal & Kingston (1992a), for Ca XX from Aggarwal & Kingston (1992b), and for Fe XXVI from Aggarwal & Kingston (1993). To distribute the collision strengths among the fine-structure levels of the LS states, we have scaled the collision strengths following the rules for the distribution of oscillator strengths under LS coupling.

As discussed in the next section, collision strengths for other ions in the hydrogen isoelectronic sequence were obtained by interpolation among the various calculated values of Aggarwal & Kingston. In the interpolation process, significant inconsistencies were found for the Ne X 1*s*-3*p*, 1*s*-3*d*, 2*s*-3*p* and 2*s*-3*d* excitations and for the Ca XX 1*s*-3*s* excitations. When interpolating the data for the necessary ions, these inconsistent rates were excluded. However, problems appear to remain for Ne X and Ca XX. The most serious discrepancies lie with the Ne X 1*s*-3*p* and 1*s*-3*d* transitions. The high temperature limit for the allowed 1*s*-3*p* collision strength derived from the oscillator strength does not appear to be consistent with the lower temperature collision strengths of Aggarwal & Kingston and is more consistent with the values of the 1*s*-3*d* collision strengths. This suggests that these collision strengths would benefit from a new calculation. We have examined the possible effect of these inconsistencies on the Ne X line intensities. On the assumption that these collision strengths have become mislabeled, we have exchanged the 1*s*-3*p* and 1*s*-3*d* collision strengths and prepared revised spline fits to the scaled collision strengths. The effect of this is to increase the Ne X 1*s*-3*p* line by a factor of about 1.4 and decrease the Ne X 1*s*-2*p* lines by a factor of about 0.9. In addition, the summed intensities of the Ne X 2*l*-3*l*′ transitions near 65.6 Å are reduced by a factor of about 0.4. In version 3 of the CHIANTI database, the original collision strengths of Aggarwal & Kingston are distributed but files containing the revised spline fits are available from the authors. No other calculations are available to check or replace these collision strength values.

3.1.2. N VII, O VIII, Na XI, Mg XII, Al XIII, S XVI, Ar XVIII, Ni XXVIII

For these hydrogenic ions, the model includes 25 fine-structure levels. The sources of the energy levels and radiative data are as above. For collision strengths, we have interpolated and extrapolated the Maxwellian-averaged collision strengths of Aggarwal & Kingston. We have found that scaling the collision strengths as $Z^2\Upsilon$ versus $T/\Delta E$, where Z is the nuclear charge, Υ the Maxwellian-averaged collision strength, T the temperature and ΔE the energy level difference, provides a slowing varying function that can be accurately interpolated and extrapolated in the case of Ni XXVIII. These interpolations indicate that the various calculations are internally consistent at about the 10%–20% level but that there are significant differences between various Aggarwal & Kingston calculations for some transitions of some ions as discussed in the previous section.

3.2. *The Helium Isoelectronic Sequence*

3.2.1. C V, N VI, O VII, Ne IX, Mg XI, Si XIII, S XV, Ca XIX, Fe XXV, Ni XXVII

For the helium isoelectronic sequence, the 49 fine-structure levels of the 1*snl* configurations, $n = 1$–5 and $l = s, p, d, f, g$ are included. Observed energies are taken from the NIST Database (Fuhr et al. 1999), with the exception of Fe XXV, whose observed energy levels come from Shirai et al. (2000). Energies of the $2s2p\ ^3P$ levels are from Chen, Cheng, & Johnson (1993). Oscillator strengths for allowed transitions are obtained from Zhang & Sampson (1987) and *A*-values derived from the oscillator strengths. For other allowed transitions, hydrogenic oscillator strengths (Wiese et al. 1966) have been used and the *A*-value derived by using the appropriate wavelength. Intercombination and forbidden decay rates from the $n = 2$ level have been taken from Lin, Johnson, & Dalgarno (1977) and the two photon decay rate from the $1s2s\ ^1S$ level has been taken from Drake (1986).

Zhang & Sampson (1987) have calculated electron collision strengths among all of the $1s^2$, 1*s*2*s* and 1*s*2*p* fine-structure levels. Sampson, Goett, & Clark (1983) provide calculations of collision strengths between the $1s^2$ ground level and the 1*snl*, $n = 2$–5, excited levels using a hydrogenic approximation. We have used these latter calculations for excitation of the $n = 3, 4, 5$ levels.

3.2.2. Na X

The treatment of the Na X ion is identical to that of the other ions of the helium isoelectronic sequences, with the following exceptions. Energies of the $2s2p\ ^3P$ levels have been taken from Curdt et al. (2000) and the collisional data

[2] Available at: http://physics.nist.gov/PhysRefData/contents.html.

have been interpolated along the isoelectronic sequence using the other available He-like ions from C V to S XV.

3.2.3. *Helium-like Dielectronic Satellites of Hydrogen-like Lines:* C V, N VI, O VII, Ne IX, Mg XI, Al XII, Si XIII, S XV, Ar XVII, Ca XIX, Ni XXVII

The model atom for describing the lines produced by dielectronic recombination consists of 95 fine-structure levels including 49 bound levels ($1snl$, $n = 1$–5) and 46 levels above the ionization potential. The energy levels and radiative rates for the 49 bound levels are the same as described above. The excitation rates for these levels are set to zero and they are populated only by cascades from levels above the ionization potential excited by dielectronic recombination. Their energy levels, radiative rates and autoionizing rates are from recent updates (Safronova & Johnson 1998) of the earlier work of Vainshtein & Safronova (1978) and Vainshtein & Safronova (1980). The effective collision strengths to these levels are derived from the total autoionizing rates following equation (3).

3.2.4. *Helium-like Dielectronic Satellites of Hydrogen-like Lines:* Fe XXV

The model atom describing the lines produced by dielectronic recombination consists of 167 levels, including 49 bound levels and 118 levels above the ionization potential. The energy levels and radiative rates for the bound levels are the same as described above. The excitation rates for these levels are set to zero and the bound levels are populated only by cascades from levels above the ionization potential excited by dielectronic recombination. For the levels above the ionization potential, we use the atomic data of Safronova (Kato et al. 1997) which includes transitions of the type $1snl$-$2l'nl''$ where $n = 2$-5. Aside from the more extensive atomic model, this ion is treated in the same manner as the others in this sequence.

3.3. *Lithium Isoelectronic Sequence*

3.3.1. O VI, Ne VIII, Mg X, Al XI, Si XII, Ar XVI, *and* Ni XXVI

As presented in Paper I, these ions are described by an atomic model that includes the $1s^2nl$ levels where $n = 2$–5. In addition, the configurations $1s2s2p$,$1s2s^2$ and $1s2p^2$ are now included. Energy levels, radiative decay probabilities and collisions strengths for these levels are from Goett & Sampson (1983). Since Goett & Sampson (1983) do not provide radiative transition probabilities for the metastable $1s2s2p\ ^4P_{5/2}$, a new set of A-values has been calculated using SSTRUCT (Eissner, Jones, & Nussbaumer 1974) with a 23 configuration model to provide such values. Autoionizing rates for these levels are from Vainshtein & Safronova (1978) and Vainshtein & Safronova (1980).

3.3.2. S XIV, Ca XVIII, Fe XXIV

The atomic data for these ions are the same as for the lithium-like ions described above except that the autoionizing rates are from Kato et al. (1997)

3.3.3. *Lithium-like Dielectronic Satellites of Helium-like Lines:* O VI, Ne VIII, Mg X, Al XI, Si XII, Ar XVI, *and* Ni XXVI

The model atom describing the lines produced by dielectronic recombination consists of 78 levels, including 24 bound levels ($1s^2nl$, $n = 1$-5) and 54 levels above the ionization potential. The energy levels and radiative rates for the 24 bound levels are the same as described above. The excitation rates for these levels are set to zero and they are populated only by cascades from levels excited by dielectronic recombination. The levels above the ionization potential have $n \leq 3$. Their energy levels, radiative rates and autoionizing rates are from recent updates (Safronova & Johnson 1998) of the earlier work of Vainshtein & Safronova (1978) and Vainshtein & Safronova (1980). The effective collision strengths to these levels are derived from the total autoionizing rates following equation (3).

3.3.4. *Lithium-like Dielectronic Satellites of Helium-like Lines:* S XIV, Ca XVIII, Fe XXIV

The model atom describing the lines produced by dielectronic recombination consists of 35 bound levels ($1s^2nl$, $n = 1$–6) and 220 (for S XIV), 249 (for Ca XVIII), and 251 (for Fe XXIV) levels above the ionization potential. The energy levels and radiative rates for the 24 bound levels are the same as described above. The excitation rates for these levels are set to zero and they are populated only by cascades from levels excited by dielectronic recombination. For the levels above the ionization potential, we use the atomic data of Safronova in Kato et al. (1997).

3.4. *Other Satellites to Helium-like* Fe XXV*:* Fe XXI, Fe XXII, Fe XXIII

Kato et al. (1997) provide the necessary atomic data to calculate the intensities of dielectronic satellite lines of Fe XXV produced by Fe XXI, Fe XXII, and Fe XXIII. These ions have also been developed in a manner identical to that described for Fe XXIV above.

3.5. *Beryllium Isoelectronic Sequence:* Mg IX

The distorted wave electron excitation data of Zhang & Sampson (1992) for the transitions between the $n = 2$ levels have been replaced by the close-coupling data of Keenan et al. (1986). The use of the Keenan et al. (1986) collision data is found to increase the populations of the $2p^2\ ^1D_2$ and $^1S_0$ levels by over 100%. This is particularly significant for the line found at 749.55 Å which arises through a decay of the $^1D_2$ level. The 706.06/749.55 line ratio has been used to determine electron temperatures from solar spectroscopic data (Wilhelm, Marsch, & Dwivedi 1998) and the revised CHIANTI model gives temperatures significantly higher than the version 2 model.

3.6. *The Carbon Isoelectronic Sequence*

For the ions N II, O III, Ne V, Na VI, and Mg VII, the transition probabilities for the $^3P_1$–$^1D_2$ and $^3P_2$–$^1D_2$ transitions within the ground configuration have been updated with the data from Storey & Zeippen (2000).

3.6.1. Fe XXI

CHIANTI version 1.0 and 2.0 included 36 fine-structure energy levels of the $2s^22p^2$, $2s2p^3$, $2p^4$, $2s^22p3s$, and $2s^22p3d$ configurations. Data for the $2s^22pnl$ ($n = 4, 5$ and $l = 0, 2$) configurations have been added so that the atomic model now includes a total of 68 fine-structure energy levels. Observed energies are taken mostly from Bromage et al. (1977), and a few remaining energies come from Shirai et al. (2000) and Kelly (1987). In a few cases, the level identifications from Bromage et al. (1977) have been corrected to

match the level ordering given by theoretical calculations. Radiative and collisional transition rates come from Phillips et al. (1996). They provide A-values and oscillator strengths for all of the most important transitions from the ground configuration to the $n = 4, 5$ levels. Collision strengths are calculated using the distorted wave approximation for three values of the incident electron energy.

3.7. *Oxygen Isoelectronic Sequence*

Transition probabilities for the ground $^3P_1$–$^1D_2$ and $^3P_2$–$^1D_2$ transitions have been updated with the data from Storey & Zeippen (2000) for the ions Ne III, Na IV, and Mg V. In addition, for Ne III, the $^3P_1$–$^1S_0$ and $^1D_2$–$^1S_0$ ground configuration transitions have been updated with the laboratory measurements of Daw et al. (2000), while updates to all other Ne III ground transition A-values are from Galavís, Mendoza, & Zeippen (1997).

3.8. *Neon Isoelectronic Sequence*

3.8.1. Ar IX, Ca XI, Ni XIX

The CHIANTI version 1.0 atomic model for Ar IX, Ca XI, and Ni XIX, described in Dere et al. (1997), was limited to 36 out of the 89 levels for which Zhang et al. (1987) provide collisional data. The reason for this was the fact that Zhang et al. 1987 do not provide radiative data for most of the $2s^22p^54l$ and $2s2p^6nl$ levels.

In the present work the SSTRUCT package (Eissner et al. 1974) has been used to generate the needed radiative transition probabilities. The atomic model adopted in the calculation closely resembles that of Zhang et al. (1987), and the results are in good agreement with the Zhang et al. (1987) values for the transitions already included in CHIANTI version 1.0.

As a result, the atomic model adopted for Ar IX, Ca XI, and Ni XIX now includes 89 levels from the $2s^22p^5nl$ and $2s2p^6nl$ configurations, with $n \leq 4$. Experimental energy levels come from a variety of sources. Ar IX energies come from the NIST database, version 2.0. The NIST database provides energies also for Ca XI, but additional energy levels are taken from the works of Crance (1973), Fawcett, Bromage, & Hayes (1979), and Kastner, Behring, & Cohen (1975). Ni XIX energy levels come from NIST database, version 2.0, with the exception of the $2p^53s\ ^3P_0$ level, whose energy has been taken from Feldman et al. (2000). Wavelengths for transitions involving levels having no experimental energy have been calculated using the Zhang et al. (1987) theoretical energies for the 36 levels included in the CHIANTI version 1 model and the SSTRUCT values for the remaining levels.

Collisional data are taken from Zhang et al. (1987) and are described in Dere et al. (1997).

3.8.2. Fe XVII

The Fe XVII atomic model has been extended to include data for the $n = 4$ configurations, for a total of 89 energy levels. Experimental energies have been taken from Shirai et al. (2000) and theoretical values come from Zhang & Sampson 1989. Radiative transition probabilities and oscillator strengths have been calculated using the SSTRUCT package (Eissner et al. 1974) including all the configurations adopted in the CHIANTI version 3.0 atomic model. Zhang & Sampson (1989) provide collision strengths for transitions between the ground level and the $n = 4$ configurations calculated for six values of the incident electron energy using a relativistic distorted wave approximation.

3.9. *Magnesium Isoelectronic Sequence*

The metastable $3s3p\ ^3P_2$ level gives rise to forbidden transitions to the $3s^2\ ^1S_0$ ground level and to the $3s3p\ ^3P_1$ level. However, in CHIANTI versions 1 and 2, the $^3P_1$–$^3P_2$ transition was not reported and its A-value was mistakenly assigned to the transition to the ground level, in all the ions of the sequence with the exception of Si III and Fe XV.

In the present version this problem has been corrected. The $^3P_1$–$^3P_2$ A-value has been taken from the NIST database and the $^1S_0$–$^3P_2$ A-value has been calculated using the SSTRUCT package (Eissner et al. 1974) since no value was found in the literature. As the rest of Mg-like radiative data have been taken from Christensen et al. (1986), the atomic model adopted in the SSTRUCT calculation is identical to that of Christensen et al. (1986) for consistency.

3.10. *Aluminum Isoelectronic Sequence*

3.10.1. Si II

Radiative data from Nahar (1998) and Nussbaumer (1977) replace some of the previous data described in Dere et al. (1997). Nahar (1998) gives oscillator strengths for the allowed transitions between the 15 levels of the CHIANTI model, while Nussbaumer (1977) gives data for the forbidden ground transition and the intercombination $3s\ ^2P$–$3p\ ^4P$ transitions.

3.10.2. S IV

Tayal (2000) has provided new electron collision data for transitions between the 52 levels of the $3s^2\ 3p$, $3s\ 3p^2$, $3p^3$, $3s^2\ 3d$, $3s\ 3p\ 3d$, $3s^2\ 4l$ ($l = s, p, d, f$) and $3s\ 3p\ 4s$ configurations. Maxwellian-averaged collision strengths are tabulated for ten temperatures between 10^4 K and 4×10^5 K. For seven transitions it was necessary to omit one or two of the upsilons in order to provide a good fit to the data. This was necessary because the five-point spline employed in the fitting procedure was inadequate to fit the data. The omitted upsilons were always at the extremes of the temperature range.

A complete set of oscillator strengths and A-values for transitions between the 52 levels are provided in Tayal (1999). The A-value for the ground transition was taken from Johnson, Kingston, & Dufton (1986). No radiative data was found in the literature for the metastable level $3s\ 3p\ 3d\ ^4F_{9/2}$ and so SSTRUCT was run with a model of the ion consisting of the configurations listed above to generate A-values to depopulate this level.

Experimental energies are available for all 52 levels and were taken from the on-line NIST database.

3.10.3. Fe XIV

New atomic data for Fe XIV are presented in Storey, Mason, & Young (2000). These authors calculated Maxwellian-averaged collision strengths (Υ) with the R-matrix method for all transitions between the 40 levels of the $3s^2\ 3p$, $3s\ 3p^2$, $3s^2\ 3d$, $3p^3$, and $3s\ 3p\ 3d$ configurations, at temperatures $5.0 \leq \log T \leq 10.0$. Only those transitions that involve the two ground configuration levels and the metastable $3s\ 3p\ 3d\ ^4\mathrm{F}_{9/2}$ level have been fitted for the

CHIANTI database as the remaining transitions have a negligible effect on the Fe XIV level populations for typical astrophysical electron densities of $N_e \lesssim 10^{14}$ cm^{-3}. For many of the transitions the variation of Υ with T was too complex to be fitted with the five-point spline that is the basis of the Burgess & Tully (1992) method and so in these cases a restricted range of temperatures had to be considered. The range over which the fits are most accurate is $5.4 \leq \log T \leq 7.0$. Comparisons of Υ's derived from the spline fits with the original data generally give excellent agreement in this temperature range, with maximum differences of 5% in a few exceptional cases. For the vast majority of data the spline fits reproduce the original data to within 1%. Consequently, the CHIANTI predicted emissivities should only be used when considering temperatures within the range $5.4 \leq \log T \leq 7.0$.

Energy levels for all but the $3s\ 3p\ 3d\ ^4F_{3/2}$ level have experimental values which have been taken from Churilov & Levashov (1993) and Redfors & Litzén (1989) and are given in Table 3 of Storey et al. (2000). For the $^4F_{3/2}$ level the energy value calculated by Storey et al. (2000) is used.

The transition probabilities in the CHIANTI .WGFA file are from Table 4 of Storey et al. (2000). The oscillator strengths are from the same calculation but were not published. The oscillator strengths in the CHIANTI .UPSDAT and .SPLUPS files are from Storey et al.'s " Basis 1 " model, which was used for the collisional calculation and so are more appropriate for the CHIANTI fitting procedures.

There are significant differences between this new Fe XIV model and the previous CHIANTI model. The consequences for interpreting solar extreme ultraviolet spectra are discussed thoroughly in Storey et al. (2000) where the discrepancies between theory and observation noted by Young et al. (1998) are found to be resolved.

3.11. *Silicon Isoelectronic Sequence*

3.11.1. S III

Tayal & Gupta (1999) have presented new R-matrix calculations for S III with Maxwellian-averaged collision strengths (upsilons) calculated for all transitions between the five levels in the $3s^2\ 3p^2$ ground configuration to the 49 levels of the $3s^2\ 3p^2$, $3s\ 3p^3$, $3s^2\ 3p\ 3d$, and $3s^2\ 3p\ 4l$ ($l = s, p, d$) configurations. Upsilons were tabulated for eight temperatures between 5×10^3 K and 1×10^5 K. For the transitions up to the $3s^2\ 3p\ 4d$ configuration, the three lowest temperature points are unreliable (S. Tayal, 2000, private communication) and so only the five highest temperature points ($2–10 \times 10^4$ K) were fitted for these transitions.

Laboratory values for all of the S III model level energies were presented by Johansson et al. (1992). Oscillator strengths and A-values for all of the allowed transitions were calculated by Tayal (1997), while A-values for transitions amongst the ground configuration levels are tabulated in Huang (1985). Upon solving the level balance equations, the $3s^2\ 3p\ 3d\ ^3F_4$ level was found to have significant population over the 10^8–10^{12} cm^{-3} range of electron densities on account of there being no allowed transitions to depopulate it. SSTRUCT was thus run with a model of the ion containing the six configurations listed above. Electric quadrupole, magnetic dipole and magnetic quadrupole A-values were computed for decays from the $^3F_4$ level, and the six strongest transitions were included.

3.11.2. Fe XIII

Gupta & Tayal (1998) provide Maxwellian-averaged collision strengths for transitions between the ground levels and the $3s3p^3$ and $3s^23p3d$ configurations. These data are calculated using the R-matrix approach and a target representation improved from the earlier R-matrix calculations by Tayal (1995). These collision strengths replace those of Fawcett & Mason (1989) used in previous versions of CHIANTI. It is important to note that no data is reported by Gupta & Tayal (1998) for the metastable $3s3p^3\ ^5S_2$ level, so the earlier collision strengths by Fawcett & Mason (1989) are used for transitions involving this level.

The other Fe XIII data are unchanged from version 1.0.

3.12. *Sulphur Isoelectronic Sequence:* Fe XI

Collisional data from Gupta & Tayal (1999) for transitions among the ground levels and between the ground and the first excited configuration have replaced the distorted wave calculations by Bhatia & Doschek (1996). Gupta & Tayal (1999) provide Maxwellian-averaged collision strengths calculated using the R-matrix method.

Gupta & Tayal (1999) compare their collision strengths with the values reported by Bhatia & Doschek (1996) at 8, 16 and 24 Rydberg, finding that most of the collisional data agree within 20%; in some cases, however, larger differences occur, probably due to electron correlation effects which are treated in a more complete way by Gupta & Tayal (1999).

The other Fe XI data have not been changed.

3.13. *Chlorine Isoelectronic Sequence:* Fe X

The Fe X model of version 2 (Landi et al. 1999, § 10.1; see also Dere et al. 1997, § 4.18) has been extended to include transitions involving levels in the $n = 4$ and $n = 5$ complexes. Collision strengths for transitions from the two levels of the $3s^2\ 3p^5$ ground configuration up to the $3s^2\ 3p^4\ 4l$ ($l = s, p, d$), $3s^2\ 3p^5\ 5l$ ($l = s, p$), $3s\ 3p^5\ 4l$ ($l = s, p$), and $3s\ 3p^5\ 5s$ configurations were taken from Malinovsky, Dubau, & Sahal-Brechot (1980).

For the $3s^2\ 3p^5$–$3s^2\ 3p^4\ 4s$ transitions, Malinovsky et al. (1980) gave collision strengths at four different values of the incoming electron energy; for all other transitions the collision strengths were only given for one value of the incoming electron energy. In assessing the $3p$–$4s$ transitions, it was often difficult to fit the four data points on account of sharp changes between consecutive points. This would seem to be due to the fact that Malinovsky et al. (1980) used the distorted wave approximation for the two lowest energy points, and a semiclassical formula due to Burgess (1964) for the two highest energy points. Note that this semiclassical formula was also used to compute the collision strengths for all of the remaining transitions.

Theoretical energy values are given by Malinovsky et al. (1980) for all of the additional levels. For 20 of these levels, observed values were available from the NIST database. No A-values were given by Malinovsky et al., and so these were calculated using SSTRUCT (Eissner et al. 1974; see also Dere et al. 1997, § 3). The new Fe X model now consists of 172 levels and predicts the intensities of some 3959 lines.

Note that Malinovsky et al. include various atomic processes that are beyond the scope of the CHIANTI database in their Fe X model, including dielectronic recombination from Fe X to Fe IX, dielectronic recombination and radiative recombination from Fe XI to Fe X, and cascading from

levels $3s^2\ 3p^4\ np$ ($n > 5$). These processes are found to have a significant effect on ratios of $3p$–$4s$ to $3p$–$3d$ transitions.

3.14. *Calcium Isoelectronic Sequence:* Fe VIII

The CHIANTI version 1 model for Fe VIII described by Dere et al. (1997) was very limited. For example, it did not include the $3p^5 3d^2$ configuration and, for this reason, CHIANTI version 1 was not able to predict several Fe VIII lines with wavelengths shorter than 170 Å. This configuration also contains many metastable levels which affect the level population calculations.

The present version of the database includes an extended Fe VIII atomic model composed of the $3p^6 3d$ ground configuration, the $3p^5 3d^2$, $3p^6 4l$ ($l = 0, 1, 2, 3$) and $3p^5 3d4s$ configurations, plus the $3p^6 nf$ ($n = 5, 6, 7$) already included in the version 1 model, for a total of 83 fine-structure levels. The data for the $n = 5, 6, 7$ levels are the same as in version 1 (Czyzak & Krueger 1966), while the radiative and collisional transition probabilities for all the other configurations come from the calculation of Griffin, Pindzola, & Badnell (2000). Experimental energy levels come from the NIST version 2 database.

However, Griffin et al. (2000) did not calculate radiative data for transitions involving the levels with $J = 9/2$ and 11/2, and it has been necessary to run the SSTRUCT code (Eissner et al. 1974) to obtain A-values for these levels. This calculation has been carried out using an extensive Fe VIII atomic model including all the relevant configurations and levels as described by Griffin et al. (2000). Radiative data have been corrected in order to take into account the differences between experimental and theoretical energy levels.

4. CONTINUUM RADIATION

New IDL procedures to calculate the free-free and free-bound continuum are supplied with the latest release of the CHIANTI. For the free-free continuum, we use the Gaunt factors of Sutherland (1998). We would point out that the units for Sutherland's equation (15) should be given as ergs $cm^{-3}\ s^{-1}\ str^{-1}\ Hz^{-1}$. For the free-bound (radiative recombination) continuum, we follow the treatment of Rybicki & Lightman (1979), except that actual energy levels are used and the Gaunt factor has been set to unity. Recombination to all levels in the CHIANTI data base are included. A procedure for calculating the two photon continuum will be released in the near future.

5. SPECTRAL LINE IDENTIFICATIONS

The iron ions Fe XVI to Fe XXVI provide a large number of observed lines in the X-ray wavelength range as well as most of the strongest ones. Due to their special importance, a careful assessment has been made of the available experimental energy levels of Fe XVI to Fe XXVI. Ab initio atomic structure calculations have been performed for each of these ions using the SSTRUCT package (Eissner et al. 1974) in order to provide an additional check on the observed energy levels available in the literature. Although the energy levels calculated by this package are not reliable for line identification purposes, the results have helped greatly to identify levels and to correct a few inconsistencies between CHIANTI energies and those found in the literature. These inconsistencies were identified by comparing the SSTRUCT-CHIANTI theoretical energies with the experimental values for all the levels with the same total angular momentum quantum number J in each configuration. In some cases 'inversions' have been found. For example, in Fe XXI the energies of the levels $2s^2 2p5d\ ^1D_2$ and $2s^2 2p5d\ ^3P_2$ have been exchanged. This has been done because the SSTRUCT energies for these two levels were different by large amounts from the experimental values, while all the energies of all the other levels having the same value of J and belonging to the same configuration showed a fairly good agreement. This agreement was also obtained with the energies of these two levels, if they were exchanged. SSTRUCT is also able to calculate the percentage of the contribution of each true LS component to the eigenfunction of each final ion level, so that it is possible to check the composition of each energy level of the CHIANTI model. In the cases where "inversions" were found, the composition of each of the two (LS-labeled) inverted levels included a large component due to the (LS-labeled) other, so that a clear assignment of LS labeling to each of the two levels is not possible. This can lead to considerable confusion in the assignment of level identification. As a rule, the agreement between observed and theoretical energies and the total angular momentum quantum number J has been taken as the criteria for assigning the experimental energies found in the literature to CHIANTI levels. Any change made to the experimental energies from the original source has been clearly labelled in the comments of the CHIANTI energy level .ELVLC files.

As a result of this assessment, the energies recently reported in Shirai et al. (2000) have been adopted for all the ions iron ions, Fe XVI through Fe XXVI, and gaps have been filled with energies from the NIST database version 2.0 (Fuhr et al. 1999) and from Kelly (1987).

Further, the experimental energy level values for ions of the boron, carbon and nitrogen isoelectronic sequences have been revised to better match solar observations. A comparison between CHIANTI wavelengths and SUMER (500–1600 Å) observations (Feldman et al. 1997; Curdt et al. 1997; Dwivedi, Curdt, & Wilhelm 1999) has shown that the CHIANTI wavelengths, based on the version 1 NIST energies, are sometimes different from the solar values with discrepancies of up to 0.5 Å. Using a semiempirical technique, Edlén extrapolated the energies of the $n = 2$ levels for the boron-like ions (Edlén 1983), the carbon-like ions (Edlén 1985) and the nitrogen-like ions (Edlén 1984). The wavelengths derived from Edlén's energy levels proved to be in better agreement with the SUMER observations and they were adopted for these sequences.

Also, for all of the $n = 2$ levels of Fe XX we have used energy levels from Edlén (1984) and for some of the $n = 2$ levels of Fe XXII we have used the values of Edlén (1983).

This assessment has demonstrated that much work is still required in order to fully understand the spectra of highly ionized iron. The available experimental energies and theoretical transition probabilities are not sufficient to reproduce the observed X-ray emission-line spectra with the desired degree of fidelity. For example, in the case of Fe XIX, Fe XX, and Fe XXII, the CHIANTI models predict a number of relatively strong spectral lines. However, these lines have apparently not been observed since they lack assignments of experimental energy levels. On the other hand, the same CHIANTI models predict a number of fairly weak lines that have apparently been observed as indicated by the assignment of experimental energy levels. We would expect that

TABLE 6

OBSERVED LINES NOT INCLUDED IN CHIANTI

λ_{solar} (Å)	Ion	Transition
1.9051	Fe XX	$1s^2\ 2s^2\ 2p^3\ {}^4S_{3/2}$–$1s\ 2s^2\ 2p^4\ {}^4P_{5/2}$
1.9075	Fe XX	$1s^2\ 2s^2\ 2p^3\ {}^2P_{3/2}$–$1s\ 2s^2\ 2p^4\ {}^2P_{3/2}$
5.223	Si XIII	$1s^2\ {}^1S_0$–$1s\ 6p\ {}^1P_1$
7.472	Fe XXIII	$2s^2\ {}^1S_0$–$2s\ 5p\ {}^1P_1$
8.977	Fe XXII	$2s\ 2p^2\ {}^2D_{5/2}$–$2s\ 2p\ ({}^3P)\ 4d\ {}^2F_{7/2}$
9.362	Ne X	$1s\ {}^2S_{1/2}$–$6p\ {}^2P_{1/2,3/2}$
9.688	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 5d\ {}^3D_3$
9.799	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^2D)\ 5d\ {}^3D_2$
9.842	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^4S)\ 5d\ {}^3D_3$
9.991	Fe XX	$2p^3\ {}^4S_{3/2}$–$2p^2\ ({}^3P)\ 4d\ {}^4P_{3/2}$
10.134	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s\ 2p^6\ 5p\ {}^3P_1$
10.386	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{1/2})\ 7d\ {}^1P_1$
10.506	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{3/2})\ 7d\ {}^3D_1$
10.564	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^2P)\ 4d\ {}^3D_2$
10.580	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^2P)\ 4d\ {}^3P_1$
10.617	Fe XIX	$2p^4\ {}^3P_0$–$2p^3\ ({}^2P)\ 4d\ {}^3D_1$
10.635	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 4d\ {}^3S_1$
10.644	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 4d\ {}^3P_2$
10.655	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{1/2})\ 6d\ {}^1P_1$
10.684	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 4d\ {}^3F_3$
10.735	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^2D)\ 4d\ {}^3S_1$
10.770	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^2D)\ 4d\ {}^3D_2$
10.770	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{3/2})\ 6d\ {}^3D_1$
10.813	Fe XIX	$2p^4\ {}^3P_2$–$2p^3\ ({}^4S)\ 4d\ {}^3D_3$
10.824	Fe XIX	$2p^4\ {}^1D_2$–$2p^3\ ({}^2D)\ 4d\ {}^1D_2$
10.933	Fe XIX	$2p^4\ {}^3P_1$–$2p^3\ ({}^4S)\ 4d\ {}^3D_2$
11.132	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{1/2})\ 5d\ {}^1P_1$
11.253	Fe XVII	$2s^2\ 2p^6\ {}^1S_0$–$2s^2\ 2p^5\ ({}^2P_{3/2})\ 5d\ {}^3D_1$
11.253	Fe XVIII	$2p^5\ {}^2P_{1/2}$–$2p^4\ ({}^1S)\ 4d\ {}^2D_{3/2}$
11.420	Fe XVIII	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 4d\ {}^2F_{5/2}$
11.458	Fe XVIII	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 4d\ {}^4F_{5/2}$
11.526	Fe XVIII	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 4d\ {}^2D_{5/2}$
17.201	Fe XVI	$2p^6\ 3p\ {}^2P_{3/2}$–$2p^5\ 3s\ 3p\ {}^2D_{5/2}$
17.370	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^1D)\ 3d\ {}^2D_{5/2}$
17.501	Fe XVI	$2p^6\ 3p\ {}^2P_{3/2}$– $2p^5\ 3s\ 3p\ {}^4P_{5/2}$
18.497	Cr XV	$2p^6\ {}^1S$–$2p^5\ ({}^2P_{1/2})\ 3d\ {}^1P_1$
19.255	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^1D)\ 3s\ {}^2D_{5/2}$
19.511	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^1D)\ 3s\ {}^2D_{3/2}$
19.538	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 3s\ {}^2P_{3/2}$
19.714	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 3s\ {}^2P_{1/2}$
19.807	Cr XVI	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^3P)\ 3s\ {}^4P_{5/2}$
20.863	Cr XV	$2p^6\ {}^1S_0$–$2p^5\ ({}^2P_{1/2})\ 3s\ {}^1P_1$
21.153	Cr XV	$2p^6\ {}^1S_0$–$2p^5\ ({}^2P_{3/2})\ 3s\ {}^3P_1$
24.110	Ca XIV	$2p^3\ {}^4S_{3/2}$–$2p^2\ ({}^3P)\ 3d\ {}^4P_{5/2}$
26.000	Ca XIII	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 3d\ {}^3P_2$
26.033	Ca XIII	$2p^4\ {}^3P_2$–$2p^3\ ({}^2D)\ 3d\ {}^3D_3$
26.219	Ca XIII	$2p^4\ {}^3P_1$–$2p^3\ ({}^2D)\ 3d\ {}^3D_2$
26.719	Ca XIII	$2p^4\ {}^3P_2$–$2p^3\ ({}^4S)\ 3d\ {}^3D_3$
27.608	Ca XII	$2p^5\ {}^2P_{1/2}$–$2p^4\ ({}^1S)\ 3d\ {}^2D_{3/2}$
27.973	Ca XII	$2p^5\ {}^2P_{3/2}$–$2p^4\ ({}^1S)\ 3d\ {}^2D_{5/2}$
28.131	Ca XII	$2p^5\ {}^2P_{1/2}$–$2p^4\ ({}^1D)\ 3d\ {}^2D_{3/2}$
32.652	Fe XVI	$3p\ {}^2P_{3/2}$–$7d\ {}^2D_{5/2}$
34.857	Fe XVI	$3p\ {}^2P_{1/2}$–$6d\ {}^2D_{3/2}$
35.106	Fe XVI	$3p\ {}^2P_{3/2}$–$6d\ {}^2D_{5/2}$
35.368	Fe XVI	$3d\ {}^2D_{5/2}$–$8f\ {}^2F_{7/2}$
35.353	Si XI	$2s\ 2p\ {}^3P_0$–$2s\ 4d\ {}^3D_1$
35.383	Si XI	$2s\ 2p\ {}^3P_1$–$2s\ 4d\ {}^3D_2$
35.446	Si XI	$2s\ 2p\ {}^3P_2$–$2s\ 4d\ {}^3D_3$
35.710	Fe XVI	$3p\ {}^2P_{1/2}$–$6s\ {}^2S_{1/2}$
36.010	Fe XVI	$3p\ {}^2P_{3/2}$–$6s\ {}^2S_{1/2}$
40.199	Fe XVI	$3d\ {}^2D_{3/2}$–$6f\ {}^2F_{5/2}$
42.543	S X	$2p^3\ {}^4S_{3/2}$–$2p^2\ ({}^3P)\ 3d\ {}^4P_{5/2}$
47.663	Ni XVII	$3s\ 3p\ {}^1P_1$–$3s\ 4d\ {}^1D_2$
47.772	Ni XVI	$3s^2\ 3p\ {}^2P_{3/2}$–$3s^2\ 4d\ {}^2D_{5/2}$

the strong lines, as predicted by CHIANTI, would be the lines associated with observed energy levels, to the contrary of what is often the case.

The importance of reliable spectral line identifications for the interpretation of high spectral resolution observations has also motivated the work of Phillips et al. (1999). They compared synthetic spectra of the MEKAL (Kaastra, Mewe, & Nieuwenhuijzen 1996) code with solar flare spectra between 5 and 20 Å observed with the high spectral resolution Flat Crystal Spectrometer (FCS) on the Solar Maximum Mission. They adjusted the wavelengths of the MEKAL spectral lines to match the FCS observations and noted the inability of the code to reproduce observed spectral line intensities in a number of cases. This work further confirms the need for continued improvements in atomic data, particularly for the Fe L-shell lines, to understand spectral observations at these important wavelengths.

6. COMPARISON WITH OBSERVED SPECTRA 1–50 Å

The CHIANTI database has been compared with observed spectra in the 1–50 Å wavelength range in order to test for correctness and completeness. We have compiled a list of observed lines from high-resolution solar spectra for this comparison, in a manner similar to Paper I. This compiled list includes observations from Acton et al. (1985, 1), Widing & Sandlin (1968, 7), Fawcett et al. (1987, 11), the revised list of Fawcett (Fawcett et al. 1987, 12) by Phillips et al. (1999), Feldman et al. (1980, 13), McKenzie et al. (1980, 14), McKenzie & Landecker (1982, 15), McKenzie et al. (1985, 16), Phillips et al. (1982, 17), Phillips et al. (1999, 18), Doschek (1972, 19), and Pike et al. (1996, 20). The numbers between 1 and 20 refer to the reference key provided in the last column of Table 5. Aside from the spectra of Widing & Sandlin (1968), all of the spectra were observed during solar flares. We have developed a composite of these spectra by combining all of the observations within a narrow wavelength interval $\Delta\lambda$ which is specified by $\Delta\lambda/\lambda = 2000$. Because of the relatively low resolution of the X-ray spectra compiled by Doschek, (1972, 19), we have not included all of these observed wavelengths.

The results of this analysis are presented in Table 5. The first column of Table 5 contains the average of the observed wavelengths of a single spectral line. The last column of Table 5 provides a key to the reference to the observations of these spectral lines. The next three columns contain the identification of the spectral line in the CHIANTI database. The second column provides the wavelength in the CHIANTI database. A blank first column indicates multiple strong lines that can be associated with the observed wavelength listed previously in the table. An ellipsis in the first column indicates a strong spectral line that is expected on the basis of the CHIANTI computed spectra that has not apparently been observed. The third and fourth column of Table 5 indicate the ion and the transition, respectively. For lines of the helium isoelectronic sequence, we have also included the notation of Gabriel (1972). Also, we would note that the helium-like level notation of NIST, used here, is somewhat different from that of other authors, such as Feldman et al. (1980). The fifth column provides the intensity of the line calculated by the CHIANTI database for a solar flare. The calculations of the line intensities assume the solar elemental abundances of Allen (1973), the ionization equilibria of Arnaud & Raymond (1992) for iron ions, Arnaud & Rothenflug (1985) for the other abundant ions

and Landini & Monsignori Fossi (1991) for the minor ions. As with Paper I, the differential emission measure of a solar flare between 3×10^4 and 2×10^7 K is taken from Dere & Cook (1979) and has been enhanced and extrapolated to 10^8 K in order to reproduce the lines at the shortest wavelengths. The line intensities are expressed in ergs per square centimeter per second per steradian. The intensity values should only be used as a guide to the identification and the amount of blending and should be used in a relative sense. The CHIANTI database predicts many more lines than are listed in Table 5, but we have not included lines below a threshold value suggested by the intensities of the lines that have been observed. Some identifications should be considered simply coincidental if the predicted intensity is low.

In Table 5 there are a number of spectral lines that have been identified and observed in solar spectra that are not included in the CHIANTI database. These are also included in Table 6 to provide a list of lines missing from the CHIANTI database. This list can be used to assess both completeness of the database and to suggest candidates for new atomic data calculations. Aside from the lines of Cr XV, all of these lines belong to ions that are included in the database but do not extend to high enough principle quantum numbers to include the necessary line. For low-resolution spectra, the missing lines could cause difficulties in fitting observed spectra. However, in the case of high-resolution spectra, usually more intense lines of the same ion are observed and reproduced by CHIANTI so that there is little loss in diagnostic capability by not including these lines.

From this comparison, it is clear that the great majority of lines observed in the X-ray spectrum of solar flares between 1 and 50 Å are included in the CHIANTI database. Consequently, we believe that CHIANTI can be used as a comprehensive diagnostic tool for collisional emission-line spectra above and below 50 Å. Nevertheless, this analysis has shown that there are still many gaps in the atomic data needed for computing X-ray spectra. The assignment of energy levels based on observed spectral line wavelengths are still needed for a large number of levels in a variety of ions. Also, calculations of collision strengths are typically only available for the lowest energy levels and these calculations need to be extended.

7. SUMMARY

The CHIANTI database has been expanded in order to interpret astrophysical spectra in the 1–50 Å wavelength region. This has primarily been accomplished by the inclusion of hydrogen-like and helium-like ions and the addition of inner-shell and dielectronic excitation of X-ray satellite lines. The atomic data for a number of other ions as been revised and updated. A detailed comparison with observed spectra has been performed to ensure the accuracy of the CHIANTI database. We believe that the new CHIANTI database will prove to be a useful tool in the interpretation of astrophysical spectra. This is of special importance at the is time because of the recent launches of the Chandra and XMM observatories which will obtain a wealth of high-resolution X-ray spectra of astrophysical sources.

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