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WEIGHTED OSCILLATOR STRENGTHS AND LIFETIMES FOR THE Si VI SPECTRUM

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ABSTRACT

The weighted oscillator strengths (gf) and the lifetimes for Si VI presented in this work were carried out in a multiconfiguration Hartree-Fock relativistic (HFR) approach. In this calculation, the electrostatic parameters were optimized by a least squares procedure, in order to improve the adjustment to experimental energy levels. This method produces gf-values that are in better agreement with intensity observations and lifetime values that are closer to the experimental ones. In this work we presented all the experimentally known electric dipole Si VI spectral lines.

Subject heading: atomic data

1. INTRODUCTION

The ground state configuration of five times ionized silicon, Si VI, is $1s^2\,2s^2\,2p^5$ with the term ^2P. Si VI belongs to the F I isoelectronic sequence. The ionization potential for Si VI is 1653900 cm^{-1} (205.06 eV). The spectrum was analyzed for the first time by Söderqvist (1934) and Ferner (1941) in the grating incidence region 65–250 Å. In 1971, Moore summarized the energy levels of Söderqvist (1934) and Ferner (1941). Griffin, Pegg, & Sellin (1976) and Träbert et al. (1976), using the beam-foil technique studied the spectra of highly ionized stripped silicon ions in the extreme ultraviolet and some Si VI lines were classified. Artru & Brillet (1977) extended the analysis of this spectrum into the VUV region. Furthermore, they improved the accuracy of the majority of the known levels. Kelly (1987) summarized all the wavelengths published for Si VI. Trigueiros et al. (1991, 1992) using laser produced plasmas analyzed the spectrum of Si VI in the VUV region.

The purpose of this work is to present a review of all known electric dipole transitions of Si VI, their oscillator strengths calculated from fitted values of the energy parameters and the lifetimes, calculated by the same method, for all known experimental energy levels. The work we present here was stimulated by the desire to determine weighted oscillator strengths and lifetimes for the Si VI spectrum. Both parameters are important in the study of laboratory and solar spectra, as silicon is an astrophysically important element. No extensive source of gf and lifetime values currently exists for this element.

2. CALCULATION

The oscillator strength $f(\gamma\gamma')$ is a physical quantity related to line intensity I and transition probability $W(\gamma\gamma')$, as given by Sobelman (1979):

$$W(\gamma\gamma') = \frac{2\omega^2 e^2}{mc^3}\,|\,f(\gamma\gamma')\,|\,, \tag{1}$$

with

$$I \propto gW(\gamma\gamma') \propto g|\,f(\gamma\gamma')\,| = gf\,.$$

Here m is the electron mass, e is the electron charge, γ is the initial quantum state, $\omega = [E(\gamma) - E(\gamma')]/\hbar$, $E(\gamma)$ is the initial state energy, $g = (2J+1)$ is the number of degenerate quantum states with angular momentum J (in the formula for the initial state). Quantities with primes refer to the final state.

In the equation above, the weighted oscillator strength, gf, is given by Cowan (1981):

$$gf = \frac{8\pi^2 mca_0^2\,\sigma}{3h}\,S\,, \tag{2}$$

where $\sigma = |E(\gamma) - E(\gamma')|/hc$, h is Planck's constant, c is light velocity, a_0 is the Bohr radius, and the electric dipole line strength is defined by

$$\boldsymbol{S} = |\langle \lambda \boldsymbol{J} \| \boldsymbol{P}^1 \| \gamma' \boldsymbol{J}' \rangle|^2\,. \tag{3}$$

This quantity is a measure of the total strength of the spectral line, including all possible transitions between $\boldsymbol{m}$, $\boldsymbol{m}'$ different J_z eigenstates. The tensor operator $\boldsymbol{P}^1$ (first order) in the reduced matrix element is the classical dipole moment for the atom in units of $-ea_0$.

To obtain gf, we need to calculate $\boldsymbol{S}$ first, or its square root:

$$\boldsymbol{S}^{1/2}_{\gamma\gamma'} = \langle \gamma \boldsymbol{J} \| \boldsymbol{P}^1 \| \gamma' \boldsymbol{J}' \rangle\,. \tag{4}$$

In a multiconfiguration calculation we have to expand the wavefunction $|\gamma J\rangle$ in terms of single configuration wavefunctions, $|\beta J\rangle$, for both upper and lower levels:

$$|\gamma J\rangle = \sum_\beta y^\gamma_{\beta J} |\beta J\rangle\,. \tag{5}$$

Therefore, we can have the multiconfigurational expression for $S^{1/2}_{\gamma\gamma'}$:

$$\boldsymbol{S}^{1/2}_{\gamma\gamma'} = \sum_\beta \sum_{\beta'} y^\gamma_{\beta J} \langle \beta \boldsymbol{J} \| \boldsymbol{P}^1 \| \beta' \boldsymbol{J}' \rangle y^{\gamma'}{}_{\beta' J'} \tag{6}$$

The probability per unit time of an atom in a specific state γJ to make a spontaneous transition to any state with lower energy is

$$P(\gamma J) = \sum A(\gamma J, \gamma' J')\,, \tag{7}$$

where $A(\gamma J, \gamma' J')$ is the Einstein spontaneous emission transition probability rate for a transition from the γJ to the $\gamma' J'$ state. The sum is over all $\gamma' J'$ states with $E(\gamma' J') < E(\gamma J)$.

The Einstein probability rate is related to gf through the following relation given by Cowan (1981):

$$gA = \frac{8\pi^2 e^2 \sigma^2}{mc}\,gf\,. \tag{8}$$

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TABLE 1

Weighted Oscillator Strengths and Spectral Lines for the Si vi Spectrum

gf-Value[a]	Int.[b]	Wavelengths[c] (Å)		Levels[d] (cm^{-1})		Configurations[e]		Terms[e]	J–J[e]	Ref.
		Observed	Calculated	Lower	Upper					
1.03×10^{-1}......	20	65.004	65.003	0	1538386	$1s^22s^22p^5$	$2s^22p^4(^1D)5d$	$^2P^o$–^2S	3/2–1/2	1
1.66×10^{-2}......	10	65.211	65.219	5090	1538386	$2s^22p^5$	$2s^22p^4(^1D)5d$	$^2P^o$–^2S	1/2–1/2	1
5.60×10^{-1}......	20	66.772	66.771	0	1497653	$2s^22p^5$	$2s^22p^4(^3P)5d$	$^2P^o$–^2D	3/2–5/2	1
4.24×10^{-2}......	10	66.796	66.796	0	1497095	$2s^22p^5$	$2s^22p^4(^1S)4d$	$^2P^o$–^2D	3/2–5/2	1
3.37×10^{-1}......	50	69.204	69.204	0	1445003	$2s^22p^5$	$2s^22p^4(^1D)4d$	$^2P^o$–^2D	3/2–5/2	1
1.59×10^{-1}......	250	69.236	69.236	0	1444335	$2s^22p^5$	$2s^22p^4(^1D)4d$	$^2P^o$–^2S	3/2–1/2	1
2.20×10^{-1}......	50	69.421	69.421	5090	1445575	$2s^22p^5$	$2s^22p^4(^1D)4d$	$^2P^o$–^2D	1/2–3/2	1
8.23×10^{-2}......	100	69.448	69.447	5090	1445027	$2s^22p^5$	$2s^22p^4(^1D)4d$	$^2P^o$–^2P	1/2–3/2	1
3.02×10^{-1}......	250	71.181	71.181	0	1404870	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2D	3/2–5/2	1
2.17×10^{-2}......	100	71.273	71.272	0	1403085	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2D	3/2–3/2	1
3.34×10^{-2}......	10	71.304	71.303	0	1402472	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2P	3/2–1/2	1
1.61×10^{-2}......	50	71.340	71.339	0	1401755	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^4P	3/2–5/2	1
1.00×10^{-4}......	150	71.366	71.366	5090	1406317	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2P	1/2–3/2	1
2.35×10^{-2}......	200	71.384	71.384	0	1400877	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^4P	3/2–3/2	1
1.89×10^{-1}......	50	71.474	71.474	0	1399117	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^4F	3/2–5/2	1
3.33×10^{-1}......	50	71.534	71.531	5090	1403085	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2D	1/2–3/2	1
5.47×10^{-2}......	50	71.561	71.562	5090	1402472	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^2P	1/2–1/2	1
2.00×10^{-4}......	10	71.644	71.644	5090	1400877	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^4P	1/2–3/2	1
1.03×10^{-1}......	10	71.718	71.718	5090	1399439	$2s^22p^5$	$2s^22p^4(^3P)4d$	$^2P^o$–^4F	1/2–3/2	1
3.94×10^{-2}......	50	72.896	72.892	0	1371884	$2s^22p^5$	$2s^22p^4(^1D)4s$	$^2P^o$–^2D	3/2–5/2	1
4.21×10^{-2}......	200	75.193	75.191	0	1329941	$2s^22p^5$	$2s^22p^4(^3P)4s$	$^2P^o$–^2P	3/2–3/2	1
7.20×10^{-3}......	50	75.486	75.480	5090	1329941	$2s^22p^5$	$2s^22p^4(^3P)4s$	$^2P^o$–^2P	1/2–3/2	1
1.14×10^{-2}......	50	75.587	75.398	0	1326302	$2s^22p^5$	$2s^22p^4(^3P)4s$	$^2P^o$–^4P	3/2–3/2	1
3.75×10^{-1}......	500	77.429	77.429	0	1291505	$2s^22p^5$	$2s^22p^4(^1S)3d$	$^2P^o$–^2D	3/2–5/2	1
2.72×10^{-1}......	300	77.718	77.718	5090	1291798	$2s^22p^5$	$2s^22p^4(^1S)3d$	$^2P^o$–^2D	1/2–3/2	1
1.97×10^{-1}......	250	80.395	80.394	0	1243878	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2D	3/2–3/2	1
1.59×10^{0}	500	80.449	80.450	0	1243012	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2D	3/2–5/2	1
2.11×10^{-1}......	250	80.491	80.489	0	1242408	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2P	3/2–1/2	1
7.83×10^{-2}......	500	80.501	80.503	0	1242190	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2F	3/2–5/2	1
1.33×10^{0}	600	80.577	80.578	0	1241035	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2P	3/2–3/2	1
6.00×10^{-1}......	500	80.698	80.698	0	1239194	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2S	3/2–1/2	1
1.01×10^{0}	500	80.725	80.724	5090	1243878	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2D	1/2–3/2	1
6.27×10^{-1}......	400	80.821	80.820	5090	1242408	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2P	1/2–1/2	1
2.91×10^{-1}......	400	80.908	80.910	5090	1241035	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2P	1/2–3/2	1
2.13×10^{-1}......	350	81.030	81.030	5090	1239194	$2s^22p^5$	$2s^22p^4(^1D)3d$	$^2P^o$–^2S	1/2–1/2	1
3.09×10^{-1}......	200	83.006	83.012	0	1204647	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2P	3/2–3/2	1
1.27×10^{0}	750	83.128	83.134	0	1202880	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2D	3/2–5/2	1
7.03×10^{-2}......	250	83.258	83.264	0	1201002	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2D	3/2–3/2	1
5.95×10^{-2}......	50	83.283	83.284	0	1200714	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2P	3/2–1/2	1
4.00×10^{-4}......	400	83.358	83.364	5090	1204647	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2P	1/2–3/2	1
1.46×10^{-2}......	400	83.526	83.491	0	1197733	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^4P	3/2–5/2	1
8.26×10^{-1}......	400	83.611	83.618	5090	1201002	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2D	1/2–3/2	1
8.40×10^{-2}......	150	83.639	83.638	5090	1200714	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2P	1/2–1/2	1
3.00×10^{-3}......	50	83.684	83.689	0	1194905	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^2P	3/2–1/2	1
1.03×10^{-1}......	50	83.729	83.729	0	1194332	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^4F	3/2–3/2	1
2.69×10^{-2}......	300	83.802	83.806	0	1193227	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^4F	3/2–5/2	1
3.00×10^{-4}......	10	83.965	83.970	5090	1195990	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^4P	1/2–3/2	1
1.96×10^{-2}......	600	84.082	84.087	5090	1194332	$2s^22p^5$	$2s^22p^4(^3P)3d$	$^2P^o$–^4F	1/2–3/2	1
6.70×10^{-2}......	200	91.370	91.371	0	1094444	$2s^22p^5$	$2s^22p^4(^1S)3s$	$^2P^o$–^2S	3/2–1/2	2
4.26×10^{-2}......	200	91.798	91.798	5090	1094444	$2s^22p^5$	$2s^22p^4(^1S)3s$	$^2P^o$–^2S	1/2–1/2	2
2.03×10^{-2}......	500	96.022	96.018	0	1041477	$2s^22p^5$	$2s^22p^4(^1D)3s$	$^2P^o$–^2D	3/2–3/2	2
1.94×10^{-1}......	500	96.488	96.489	5090	1041477	$2s^22p^5$	$2s^22p^4(^1D)3s$	$^2P^o$–^2D	1/2–3/2	2
1.02×10^{-1}......	500	99.096	99.096	0	1009122	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^2P	3/2–1/2	2
4.88×10^{-1}......	750	99.459	99.459	0	1005436	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^2P	3/2–3/2	2
1.86×10^{-1}......	500	99.599	99.598	5090	1009122	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^2P	1/2–1/2	2
7.90×10^{-2}......	500	99.966	99.965	5090	1005436	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^2P	1/2–3/2	2
6.00×10^{-4}......	10	100.159	100.159	5090	993634	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^4P	1/2–3/2	2
7.50×10^{-3}......	500	100.640	100.641	0	993634	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^4P	3/2–3/2	2
8.00×10^{-4}......	40	100.953	100.957	0	990523	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^4P	3/2–5/2	2
9.00×10^{-4}......	10	100.970	100.971	5090	995477	$2s^22p^5$	$2s^22p^4(^3P)3s$	$^2P^o$–^4P	1/2–1/2	2
9.50×10^{-2}......	50	102.846	102.846	406497	1378824	$2s2p^6$	$2s2p^5(^3P)3s$	^2S–$^2P^o$	1/2–1/2	1
1.84×10^{-1}......	100	103.163	103.163	406497	1375836	$2s2p^6$	$2s2p^5(^3P)3s$	^2S–$^2P^o$	1/2–3/2	1
9.00×10^{-5}......	50	147.800	147.817	406497	1083009	$2s2p^6$	$2s^22p^4(^3P)3p$	^2S–$^4D^o$	1/2–1/2	3
9.00×10^{-5}......	50	213.400	213.435	1069861	1538386	$2s^22p^4(^3P)3p$	$2s^22p^4(^1D)5d$	$^4P^o$–^2S	3/2–1/2	3

TABLE 1—*Continued*

gf-Value[a]	Int.[b]	Wavelengths[c] (Å) Observed	Calculated	Levels[d] (cm^{-1}) Lower	Upper	Configurations[e]		Terms[e]	J–J[e]	Ref.
1.46×10^{-2}……	50	224.100	224.109	1092176	1538386	$2s^22p^4(^3P)3p$	$2s^22p^4(^1D)5d$	$^2P^o-^2S$	3/2–1/2	3
4.04×10^{-1}……	800	246.004	246.005	0	406497	$2s^22p^5$	$2s2p^6$	$^2P^o-^2S$	3/2–1/2	2,3
2.00×10^{-1}……	700	249.124	249.124	5090	406497	$2s^22p^5$	$2s2p^6$	$^2P^o-^2S$	1/2–1/2	2,3
3.00×10^{-4}……		281.230	281.229	1182804	1538386	$2s^22p^4(^1S)3p$	$2s^22p^4(^1D)5d$	$^2P^o-^2S$	3/2–1/2	4
8.50×10^{-3}……	50	281.300	281.314	1089553	1445027	$2s^22p^4(^3P)3p$	$2s^22p^4(^1D)4d$	$^2D^o-^2P$	3/2–3/2	3
1.00×10^{-2}……		285.920	285.920	1147905	1497653	$2s^22p^4(^1D)3p$	$2s^22p^4(^3P)5d$	$^2P^o-^2D$	3/2–5/2	4
9.00×10^{-5}……		301.250	301.251	1071134	1403085	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^4P^o-^2D$	1/2–3/2	4
2.59×10^{-1}……	2	308.481	308.481	1068819	1392988	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^4P^o-^4D$	5/2–5/2	5
5.49×10^{-1}……	3	308.703	308.703	1068819	1392755	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^4P^o-^4D$	5/2–7/2	5
6.88×10^{-1}……	8	314.348	314.348	1123549	1441668	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4d$	$^2F^o-^2G$	5/2–7/2	5
8.91×10^{-1}……	2	314.922	314.922	1124218	1441758	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4d$	$^2F^o-^2G$	7/2–9/2	5
8.28×10^{-1}……	6	315.094	315.094	1078940	1396306	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^4D^o-^4F$	7/2–9/2	5
4.80×10^{-1}……	2	315.730	315.730	1080706	1397433	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^4D^o-^4F$	5/2–7/2	5
1.13×10^{-1}……	2	318.025	318.025	1086802	1401243	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^2D^o-^2F$	5/2–7/2	5
1.53×10^{-1}……	1	319.241	319.241	1089553	1402796	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4d$	$^2D^o-^2F$	3/2–5/2	5
3.78×10^{-1}……	4	321.900	321.925	1134500	1445156	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4d$	$^2D^o-^2F$	5/2–7/2	5
9.00×10^{-5}……	50	331.200	331.100	1069861	1371884	$2s^22p^4(^3P)3p$	$2s^22p^4(^1D)4s$	$^4P^o-^2D$	3/2–5/2	3,4
9.00×10^{-5}……	50	360.300	360.313	1124218	1401755	$2s^22p^4(^1D)3p$	$2s^22p^4(^3P)4d$	$^2F^o-^4P$	7/2–5/2	3
1.21×10^{-1}……	2	386.430	386.433	1069861	1328637	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4P^o-^4P$	3/2–1/2	5
1.04×10^{-1}……	1	389.132	389.160	1147905	1404870	$2s^22p^4(^1D)3p$	$2s^22p^4(^3P)4d$	$^2P^o-^2D$	3/2–5/2	5
5.12×10^{-1}……	4	392.271	392.269	1068819	1323746	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4P^o-^4P$	5/2–5/2	5
2.35×10^{-1}……	3	393.874	393.878	1069861	1323746	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4P^o-^4P$	3/2–5/2	5
5.30×10^{-1}……	4	402.635	402.634	1123549	1371913	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4s$	$^2F^o-^2D$	5/2–3/2	5
7.73×10^{-1}……	8	403.770	403.770	1124218	1371913	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4s$	$^2F^o-^2D$	7/2–5/2	5
1.94×10^{-1}……	4	405.816	405.813	1082218	1328637	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4D^o-^4P$	3/2–1/2	5
4.48×10^{-1}……	5	407.161	407.174	1080706	1326302	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4D^o-^4P$	5/2–3/2	5
7.63×10^{-1}……	7	408.490	408.488	1078940	1323746	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4D^o-^4P$	7/2–5/2	5
1.58×10^{-1}……	2	409.695	409.696	1082218	1326302	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4D^o-^4P$	3/2–3/2	5
1.62×10^{-1}……	4	411.152	411.152	1089553	1332772	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^2D^o-^2P$	3/2–1/2	5
4.72×10^{-1}……	4	411.278	411.286	1086801	1329941	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^2D^o-^2P$	5/2–3/2	5
1.01×10^{-1}……	4	411.482	411.456	1080706	1323746	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4D^o-^4P$	5/2–5/2	5
1.42×10^{-1}……	1	416.001	415.993	1089553	1329941	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^2D^o-^2P$	3/2–3/2	5
3.04×10^{-1}……	2	420.468	420.472	1134085	1371913	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4s$	$^2D^o-^2D$	3/2–3/2	5
4.40×10^{-1}……	3	421.238	421.258	1134500	1371884	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)4s$	$^2D^o-^2D$	5/2–5/2	5
1.09×10^{-1}……	1	430.034	430.027	1093758	1326302	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)4s$	$^4S^o-^4P$	3/2–3/2	5
4.35×10^{-1}……	0	431.409	431.406	1181655	1413456	$2s^22p^4(^3P)3d$	$2p^4(^3P_0)4f$	$^4D-[3]^o$	5/2–7/2	6
7.61×10^{-1}……	2	433.607	433.640	1181173	1411779	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4D-[4]^o$	7/2–9/2	6
1.28×10^{-1}……	1	434.782	434.806	1093758	1323746	$2s^22p^4(^3P)3p$	$2p^4(^3P)4s$	$^4S^o-^4P$	3/2–5/2	5
5.65×10^{-1}……	1	436.281	436.281	1182317	1411527	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4D-[2]^o$	3/2–5/2	6
6.27×10^{-1}……	2	437.512	437.513	1182900	1411464	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4D-[2]^o$	1/2–3/2	6
4.61×10^{0} ……	7	442.951	440.659	1181173	1408106	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[4]^o$	7/2–9/2	6
8.76×10^{-1}……	2	443.531	443.532	1181655	1407118	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[3]^o$	5/2–5/2	6
1.37×10^{-1}……	5	443.814	443.814	1181655	1406975	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[4]^o$	5/2–7/2	6
2.82×10^{-2}……	3	443.952	443.954	1182317	1407565	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[2]^o$	3/2–3/2	6
1.44×10^{0} ……	4	444.836	444.837	1182317	1407118	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[3]^o$	3/2–5/2	6
8.38×10^{-1}……	2	445.108	445.105	1182900	1407565	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4D-[2]^o$	1/2–3/2	6
2.50×10^{-1}……	4	446.461	446.470	1147905	1371884	$2s^22p^4(^1D)3p$	$2p^4(^1D)4s$	$^2P^o-^2D$	3/2–5/2	5
1.00×10^{0} ……	3	448.695	448.673	1232671	1455550	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	$^2G-[4]^o$	9/2–9/2	6
2.30×10^{-2}……	3	448.695	448.701	1232671	1455537	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	$^2G-[4]^o$	9/2–7/2	6
1.34×10^{-1}……	1	451.213	451.210	1150287	1371913	$2s^22p^4(^1D)3p$	$2p^4(^1D)4s$	$^2P^o-^2D$	1/2–3/2	5
1.37×10^{-1}……	9	452.171	452.171	1232671	1453827	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	$^2G-[5]^o$	9/2–9/2	6
7.33×10^{0} ……	9	452.171	452.171	1232671	1453827	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	$^2G-[5]^o$	9/2–11/2	6
2.43×10^{0} ……	5	454.058	454.065	1191546	1411779	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4F-[4]^o$	7/2–9/2	6
1.74×10^{0} ……	3	456.295	456.292	1194332	1413490	$2s^22p^4(^3P)3d$	$2p^4(^3P_0)4f$	$^4F-[3]^o$	3/2–5/2	6
2.69×10^{0} ……	4	457.413	457.413	1193227	1411848	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4F-[4]^o$	5/2–7/2	6
7.49×10^{0} ……	7	457.815	457.815	1189850	1408279	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4F-[5]^o$	9/2–11/2	6
6.49×10^{-1}……	3	458.449	458.447	1194332	1412460	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4F-[3]^o$	3/2–5/2	6
9.97×10^{-1}……	2	460.675	460.675	1189850	1408106	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4F-[4]^o$	9/2–9/2	6
3.06×10^{0} ……	10	461.314	461.285	1194993	1411779	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^2F-[4]^o$	7/2–9/2	6
3.32×10^{0} ……	10	461.314	461.320	1191546	1408316	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	$^4F-[5]^o$	7/2–9/2	6
3.41×10^{-1}……	0	461.767	461.766	1194905	1411464	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4P-[2]^o$	1/2–3/2	6
7.00×10^{-4}……	20	462.290	462.292	1182804	1399117	$2s^22p^4(^1S)3p$	$2p^4(^3P)4d$	$^2P^o-^4F$	3/2–5/2	2
8.01×10^{-1}……	5	462.312	462.315	1197153	1413456	$2s^22p^4(^3P)3d$	$2p^4(^3P_0)4f$	$^2F-[3]^o$	5/2–7/2	6
1.41×10^{0} ……	3	463.962	463.957	1195990	1411527	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^4P-[2]^o$	3/2–5/2	6
1.80×10^{0} ……	2	464.656	464.640	1197153	1412373	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	$^2F-[3]^o$	5/2–7/2	6

TABLE 1—*Continued*

		Wavelengths[c] (Å)		Levels[d] (cm^{-1})		Configurations[e]				
gf-Value[a]	Int.[b]	Observed	Calculated	Lower	Upper			Terms[e]	J–J[e]	Ref.
2.35×10^{0}	6	465.881	465.896	1197733	1412373	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^4P–$[3]^o$	5/2–7/2	6
4.98×10^{-1}......	1	467.735	467.740	1197733	1411527	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^4P–$[2]^o$	5/2–5/2	6
5.34×10^{-1}......	1	467.897	467.886	1194905	1408632	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^4P–$[1]^o$	1/2–3/2	6
8.62×10^{-1}......	2	468.149	468.149	1194905	1408512	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^4P–$[1]^o$	1/2–1/2	6
7.52×10^{-1}......	3	468.530	468.530	1239194	1452628	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2S–$[1]^o$	1/2–1/2	6
1.19×10^{0}	3	468.530	468.530	1239194	1452628	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2S–$[1]^o$	1/2–3/2	6
4.11×10^{0}	8	468.780	468.722	1242190	1455537	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[4]^o$	5/2–7/2	6
2.93×10^{0}	8	468.780	468.774	1194993	1408316	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2F–$[5]^o$	7/2–9/2	6
1.25×10^{0}	3	469.611	469.614	1242190	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[3]^o$	5/2–5/2	6
3.40×10^{-2}......	3	469.611	469.614	1242190	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[3]^o$	5/2–7/2	6
1.21×10^{-1}......	7	469.728	469.778	1242670	1455537	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[4]^o$	7/2–7/2	6
5.50×10^{0}	7	469.728	469.748	1242670	1455537	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[4]^o$	7/2–9/2	6
2.00×10^{0}	3	469.832	469.833	1241035	1453877	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2P–$[2]^o$	3/2–5/2	6
5.64×10^{-1}......	1	470.263	470.274	1195990	1408632	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^4P–$[1]^o$	3/2–3/2	6
5.08×10^{-2}......	2	470.677	470.674	1242670	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[3]^o$	7/2–5/2	6
1.54×10^{0}	2	470.677	470.674	1242670	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2F–$[3]^o$	7/2–7/2	6
3.00×10^{-4}......	1	471.021	471.007	1194993	1407304	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2F–$[3]^o$	7/2–7/2	6
5.44×10^{-2}......	3	471.433	471.433	1243012	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2D–$[3]^o$	5/2–5/2	6
3.46×10^{0}	3	471.433	471.433	1243012	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2D–$[3]^o$	5/2–7/2	6
5.17×10^{-1}......	1	471.873	471.738	1194993	1406975	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2F–$[4]^o$	7/2–7/2	6
6.44×10^{-2}......	1	472.228	472.226	1195990	1407753	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^4P–$[2]^o$	3/2–5/2	6
1.16×10^{0}	3	472.860	472.859	1242408	1453888	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2P–$[2]^o$	1/2–3/2	6
2.40×10^{0}	3	473.366	473.365	1243878	1455132	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2D–$[3]^o$	3/2–5/2	6
1.40×10^{0}	4	474.238	474.238	1243012	1453877	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2D–$[2]^o$	5/2–5/2	6
1.04×10^{0}	2	475.000	475.002	1201002	1411527	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^2D–$[2]^o$	3/2–5/2	6
7.95×10^{-2}......	3	475.850	475.848	1197153	1407304	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2F–$[3]^o$	5/2–7/2	6
8.91×10^{-1}......	2	476.169	476.170	1243878	1453888	$2s^22p^4(^1D)3d$	$2p^4(^1D_2)4f$	^2D–$[2]^o$	3/2–3/2	6
8.47×10^{-2}......	1	477.151	477.166	1197733	1407304	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^4P–$[3]^o$	5/2–7/2	6
1.92×10^{0}	2	478.541	478.542	1202880	1411848	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^2D–$[4]^o$	5/2–7/2	6
6.07×10^{-2}......	3	478.826	478.829	1204647	1412460	$2s^22p^4(^3P)3d$	$2p^4(^3P_0)4f$	^2P–$[3]^o$	3/2–5/2	6
2.17×10^{0}	2	481.202	481.204	1204647	1412460	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^2P–$[3]^o$	3/2–5/2	6
5.83×10^{-2}......	1	483.374	483.372	1204647	1411527	$2s^22p^4(^3P)3d$	$2p^4(^3P_1)4f$	^2P–$[2]^o$	3/2–5/2	6
7.04×10^{-1}......	3	483.671	483.674	1201002	1407753	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2D–$[2]^o$	3/2–5/2	6
2.46×10^{-1}......	1	485.165	485.162	1201002	1407118	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2D–$[3]^o$	3/2–5/2	6
1.06×10^{-1}......	4	489.179	489.179	1202880	1407304	$2s^22p^4(^3P)3d$	$2p^4(^3P_2)4f$	^2D–$[3]^o$	5/2–7/2	6
1.00×10^{-4}......		504.950	504.950	1093758	1291798	$2s^22p^4(^3P)3p$	$2s^22p^4(^1S)3d$	$^4S^o$–^2D	3/2–3/2	4
6.83×10^{-2}......	90	690.350	690.363	1005436	1150287	$2s^22p^4(^3P)3s$	$2s^22p^4(^1D)3p$	^2P–$^2P^o$	3/2–1/2	2
4.32×10^{-1}......	90	701.890	701.903	1005436	1147905	$2s^22p^4(^3P)3s$	$2s^22p^4(^1D)3p$	^2P–$^2P^o$	3/2–3/2	2
1.68×10^{-1}......	60	708.394	708.394	1009122	1150287	$2s^22p^4(^3P)3s$	$2s^22p^4(^1D)3p$	^2P–$^2P^o$	1/2–1/2	2
9.61×10^{-2}......	40	720.547	720.550	1009122	1147905	$2s^22p^4(^3P)3s$	$2s^22p^4(^1D)3p$	^2P–$^2P^o$	1/2–3/2	2
3.89×10^{-1}......	20	775.710	775.708	1068819	1197733	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	5/2–5/2	2
9.00×10^{-5}......	20	779.190	779.216	1068819	1197153	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^2F	5/2–5/2	2
2.81×10^{-1}......	10	782.030	782.027	1069861	1197733	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	3/2–5/2	2
1.40×10^{-3}......	5	785.570	785.592	1069861	1197153	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^2F	3/2–5/2	2
2.19×10^{-1}......	10	786.343	786.342	1068819	1195990	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	5/2–3/2	2
4.42×10^{-2}......	5	792.860	792.836	1069861	1195990	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	3/2–3/2	2
2.54×10^{-1}......	30	799.723	799.718	1069861	1194905	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	3/2–1/2	2
3.18×10^{-1}......	30	800.926	800.928	1071134	1195990	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	1/2–3/2	2
8.15×10^{-2}......	5	807.940	807.952	1071134	1194905	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4P	1/2–1/2	2
8.43×10^{-1}......	20	844.219	844.226	1124218	1242670	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)3d$	$^2F^o$–^2F	7/2–7/2	2
9.00×10^{-4}......	5	874.990	874.993	1080706	1194993	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^2F	5/2–7/2	2
1.31×10^{-1}......	10	884.640	884.647	1069861	1182900	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	3/2–1/2	2
6.68×10^{-1}......	60	886.243	886.236	1068819	1181655	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	5/2–5/2	2
2.86×10^{-1}......	10	888.050	888.056	1078940	1191546	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	7/2–7/2	2
4.12×10^{-1}......	20	888.720	888.726	1080706	1193227	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	5/2–5/2	2
6.20×10^{-1}......	50	889.227	889.230	1069861	1182317	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	3/2–3/2	2
1.79×10^{0}	100	890.041	890.043	1068819	1181173	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	5/2–7/2	2
2.80×10^{-1}......		891.970	891.954	1082218	1194332	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	3/2–3/2	2
7.97×10^{-1}......	70	894.490	894.493	1069861	1181655	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	3/2–5/2	2
3.82×10^{-1}......	40	894.737	894.734	1071134	1182900	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	1/2–1/2	2
7.91×10^{-1}......	40	898.281	898.286	1083009	1194332	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	1/2–3/2	2
2.82×10^{-1}......	40	899.427	899.422	1071134	1182317	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4P^o$–^4D	1/2–3/2	2
1.55×10^{0}	60	900.834	900.832	1082218	1193227	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	3/2–5/2	2
3.34×10^{0}	200	901.637	901.637	1078940	1189850	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	7/2–9/2	2
2.37×10^{0}	100	902.209	902.202	1080706	1191546	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4F	5/2–7/2	2

TABLE 1—*Continued*

		WAVELENGTHS[c] (Å)		LEVELS[d] (cm^{-1})						
gf-VALUE[a]	INT.[b]	Observed	Calculated	Lower	Upper	CONFIGURATIONS[e]		TERMS[e]	J–J[e]	REF.
4.19×10^{-1}......	5	906.180	906.195	1086801	1197153	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^2D^o$–^2F	5/2–5/2	2
3.73×10^{-1}......	30	919.034	919.031	1041477	1150287	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2P^o$	3/2–1/2	2
3.35×10^{0}	90	922.063	922.063	1124218	1232671	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)3d$	$^2F^o$–^2G	7/2–9/2	2
2.62×10^{0}	100	924.290	924.286	1086801	1194993	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^2D^o$–^2F	5/2–7/2	2
1.72×10^{0}	50	924.496	924.470	1134500	1242670	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)3d$	$^2D^o$–^2F	5/2–7/2	2
1.04×10^{0}	5	925.030	925.026	1134085	1242190	$2s^22p^4(^1D)3p$	$2s^22p^4(^1D)3d$	$^2D^o$–^2F	3/2–5/2	2
1.46×10^{0}		929.389	929.369	1089553	1193227	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^2D^o$–^4F	3/2–5/2	2
6.64×10^{-1}......		939.100	939.071	1041417	1147905	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2P^o$	5/2–3/2	2
5.30×10^{-3}......	5	954.700	954.701	1086801	1191546	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^2D^o$–^4F	5/2–7/2	2
1.05×10^{0}	40	961.766	961.770	1093758	1197733	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4S^o$–^4P	3/2–5/2	2
3.84×10^{-1}......	60	968.655	968.657	990523	1093758	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4S^o$	5/2–3/2	2
1.09×10^{-1}......	5	973.570	973.570	1078940	1181655	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4D	7/2–5/2	2
6.02×10^{-1}......	70	978.167	978.161	1093759	1195990	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4S^o$–^4P	3/2–3/2	2
5.76×10^{-1}......	70	978.167	978.166	1078941	1181173	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4D	7/2–7/2	2
2.75×10^{-1}......	30	988.664	988.667	1093758	1194905	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4S^o$–^4P	3/2–1/2	2
1.83×10^{-1}......	50	990.590	990.598	1080706	1181655	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4D	5/2–5/2	2
3.30×10^{-1}......	60	997.884	998.755	993634	1093758	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4S^o$	3/2–3/2	2
4.77×10^{-2}......	5	1001.090	1001.091	1083009	1182900	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4D	1/2–1/2	2
5.58×10^{-2}......	5	1006.960	1006.963	1083009	1182317	$2s^22p^4(^3P)3p$	$2s^22p^4(^3P)3d$	$^4D^o$–^4D	1/2–3/2	2
1.89×10^{-1}......	40	1017.470	1017.489	995477	1093758	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4S^o$	1/2–3/2	2
1.17×10^{0}	50	1074.360	1074.309	1041417	1134500	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2D^o$	5/2–5/2	2
1.18×10^{-1}......	5	1074.980	1074.996	1041477	1134500	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2D^o$	3/2–5/2	2
8.03×10^{-1}......	30	1079.809	1079.809	1041477	1134085	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2D^o$	3/2–3/2	2
2.38×10^{-1}......	40	1108.850	1108.846	990523	1080706	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	5/2–5/2	2
4.11×10^{-1}......	30	1128.990	1128.860	993634	1082218	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	3/2–3/2	2
1.71×10^{0}	100	1130.983	1130.989	990523	1078940	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	5/2–7/2	2
3.70×10^{-1}......	50	1142.430	1142.443	995477	1083009	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	1/2–1/2	2
9.98×10^{-1}......	90	1148.630	1148.464	993634	1080706	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	3/2–5/2	2
2.24×10^{-1}......	70	1152.862	1152.867	1005436	1092176	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^2P–$^2P^o$	3/2–3/2	2
4.13×10^{-1}......	70	1152.862	1152.852	995477	1082218	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4D^o$	1/2–3/2	2
3.66×10^{-1}......	50	1188.829	1188.811	1005436	1089553	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^2P–$^2D^o$	3/2–3/2	2
3.42×10^{-1}......	80	1204.050	1204.045	1009122	1092176	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^2P–$^2P^o$	1/2–3/2	2
1.64×10^{0}	200	1207.680	1207.707	1041417	1124218	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2F^o$	5/2–7/2	2
1.09×10^{-1}......	10	1217.416	1217.553	1041417	1123549	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2F^o$	5/2–5/2	2
1.11×10^{0}	100	1218.500	1218.435	1041477	1123549	$2s^22p^4(^1D)3s$	$2s^22p^4(^1D)3p$	^2D–$^2F^o$	3/2–5/2	2
1.16×10^{0}	300	1229.010	1229.014	1005436	1086801	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^2P–$^2D^o$	3/2–5/2	2
3.92×10^{-1}......	50	1243.310	1243.306	1009122	1089553	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^2P–$^2D^o$	1/2–3/2	2
8.72×10^{-1}......	500	1277.200	1277.201	990523	1068819	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4P^o$	5/2–5/2	2
3.10×10^{-1}......	100	1290.490	1290.303	993634	1071134	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4P^o$	3/2–1/2	2
1.07×10^{-1}......	50	1312.640	1311.874	993634	1069861	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4P^o$	3/2–3/2	2
1.91×10^{-1}......	90	1330.270	1330.049	993634	1068819	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4P^o$	3/2–5/2	2
1.89×10^{-1}......	80	1344.400	1344.388	995477	1069861	$2s^22p^4(^3P)3s$	$2s^22p^4(^3P)3p$	^4P–$^4P^o$	1/2–3/2	2

[a] Weighted oscillator strengths for atomic transition obtained by the method described in § 2.
[b] Observed line intensities.
[c] Wavelength corresponding to the energy levels difference between the experimental adjusted energy level values.
[d] Numerical values of the energy levels are those obtained by an optimized procedure using the program ELCALC.
[e] Level designations for the transition, including configuration parentage, term, and total angular momentum. For pratical purposes, we show them in three separate columns.

REFERENCES.—(1) Ferner 1941; (2) Artru & Brillet 1977; (3) Griffin et al. 1976; (4) Träbert et al. 1976; (5) Trigueiros et al. 1992; (6) Trigueiros et al. 1991.

Since the natural lifetime $\tau(\gamma J)$ is the inverse of the probability $P(\gamma J)$, then

$$\tau(\gamma J) = [\sum A(\gamma J, \gamma' J')]^{-1} . \quad (9)$$

Natural lifetime is applicable to an isolated atom. Interaction with matter or radiation will reduce the lifetime of a state.

The values for gf and lifetime given in Tables 1 and 2, respectively, were calculated according to these equations.

In order to obtain better values for oscillator strengths, we calculated the reduced matrix elements $\boldsymbol{P}^1$ by using optimized values of energy parameters, which were adjusted from a least squares calculation. In this adjustment, the code tries to fit experimental energy values by varying the electrostatic parameters. This procedure improves σ-values used in equation (2) and $y^{\gamma}_{\beta J}$- and $y^{\gamma'}_{\beta' J'}$-values used in equation (6). The energy parameters of this calculation are given by Coutinho (1998).

3. DISCUSSION

The theoretical predictions for the energy levels of the configurations were obtained by diagonalizing the energy matrices with appropriate Hartree-Fock relativistic (HFR) values for the energy parameters. For this purpose the computer code developed by Cowan (1981) was used. The interpretation of the configuration level structures were made by

TABLE 2

LIFETIMES FOR THE Si VI SPECTRUM

Configuration	Terms	Energy (cm^{-1})	Lifetimes[a] (ns)	Configuration	Terms	Energy (cm^{-1})	Lifetimes[a] (ns)
$2s^22p^5$	$^2P_{3/2}$	0	...	$2s^22p^4(^3P_0)4f$......	$[3]_{7/2}$	1413456	0.0490
	$^2P_{1/2}$	5090	...		$[3]_{5/2}$	1413490	0.0492
$2s^22p^4(^3P)3p$	$^4P_{5/2}$	1068819	1.4030	$2s^22p^4(^1D_2)4f$......	$[1]_{1/2}$	1452628	0.0436
	$^4P_{3/2}$	1069861	1.4080		$[1]_{3/2}$	1452628	0.0436
	$^4P_{1/2}$	1071134	1.4260		$[5]_{9/2}$	1453827	0.0533
	$^4D_{7/2}$	1078940	0.8989		$[5]_{11/2}$	1453827	0.0534
	$^4D_{5/2}$	1080706	0.9293		$[2]_{5/2}$	1453877	0.0448
	$^4D_{3/2}$	1082218	0.9215		$[2]_{3/2}$	1453888	0.0450
	$^4D_{1/2}$	1083009	0.9173		$[3]_{5/2}$	1455132	0.0472
	$^2D_{5/2}$	1086801	1.1280		$[3]_{7/2}$	1455132	0.0471
	$^2D_{3/2}$	1089553	1.1220		$[4]_{7/2}$	1455537	0.0500
	$^2P_{3/2}$	1092176	1.0390		$[4]_{9/2}$	1455550	0.0500
	$^4S_{3/2}$	1093758	0.6452	$2s2p^6$..............	$^2S_{1/2}$	406497	0.0304
$2s^22p^4(^1D)3p$	$^2F_{5/2}$	1123549	1.0950	$2s^22p^4(^3P)3s$.......	$^4P_{5/2}$	990523	12.2100
	$^2F_{7/2}$	1124218	1.0690		$^4P_{3/2}$	993634	0.7507
	$^2D_{3/2}$	1134085	0.7971		$^4P_{1/2}$	995477	3.2690
	$^2D_{5/2}$	1134500	0.7966		$^2P_{3/2}$	1005436	0.0105
	$^2P_{3/2}$	1147905	0.2301		$^2P_{1/2}$	1009122	0.0103
	$^2P_{1/2}$	1150287	0.2272	$2s^22p^4(^1D)3s$	$^2D_{5/2}$	1041417	0.0259
$2s^22p^4(^1S)3p$	$^2P_{3/2}$	1182804	0.7199		$^2D_{3/2}$	1041477	0.0261
$2s2p^5(^3P)3s$........	$^2P_{3/2}$	1375836	0.0214	$2s^22p^4(^1S)3s$	$^2S_{1/2}$	1094444	0.0230
	$^2P_{1/2}$	1378824	0.0207	$2s^22p^4(^3P)3d$	$^4D_{7/2}$	1181173	0.4124
$2s^22p^4(^3P_2)4f$......	$[4]_{7/2}$	1406975	0.0511		$^4D_{5/2}$	1181655	0.4081
	$[3]_{5/2}$	1407118	0.0485		$^4D_{3/2}$	1182317	0.3847
	$[3]_{7/2}$	1407304	0.0483		$^4D_{1/2}$	1182900	0.3516
	$[2]_{3/2}$	1407565	0.0474		$^4F_{9/2}$	1189850	0.3442
	$[2]_{5/2}$	1407753	0.0493		$^4F_{7/2}$	1191546	0.3447
	$[4]_{9/2}$	1408106	0.0486		$^4F_{5/2}$	1193227	0.1392
	$[5]_{11/2}$	1408279	0.0520		$^4F_{3/2}$	1194332	0.0313
	$[5]_{9/2}$	1408316	0.0523		$^4P_{1/2}$	1194905	0.2546
	$[1]_{1/2}$	1408512	0.0467		$^2F_{7/2}$	1194993	0.0363
	$[1]_{3/2}$	1408632	0.0474		$^4P_{3/2}$	1195990	0.2480
$2s^22p^4(^3P_1)4f$......	$[2]_{3/2}$	1411464	0.0472		$^2F_{5/2}$	1197153	0.0143
	$[2]_{5/2}$	1411527	0.0477		$^4P_{5/2}$	1197733	0.2094
	$[4]_{9/2}$	1411779	0.0507		$^2P_{1/2}$	1200714	0.0143
	$[4]_{7/2}$	1411848	0.0514		$^2D_{3/2}$	1201002	0.0046
	$[3]_{7/2}$	1412373	0.0490		$^2D_{5/2}$	1202880	0.0049
	$[3]_{5/2}$	1412460	0.0498		$^2P_{3/2}$	1204647	0.0131
$2s^22p^4(^1D)3d$	$^2G_{9/2}$	1232671	0.3386	$2s^22p^4(3P)4d$	$^4F_{7/2}$	1397433	0.1884
	$^2S_{1/2}$	1239194	0.0024		$^4F_{5/2}$	1399117	0.0216
	$^2P_{3/2}$	1241035	0.0024		$^4F_{3/2}$	1399439	0.0252
	$^2F_{5/2}$	1242190	0.0621		$^4P_{3/2}$	1400877	0.0779
	$^2P_{1/2}$	1242408	0.0024		$^4P_{5/2}$	1401755	0.1184
	$^2F_{7/2}$	1242670	0.3731		$^2P_{1/2}$	1402472	0.0163
	$^2D_{5/2}$	1243012	0.0037		$^2F_{5/2}$	1402796	0.0142
	$^2D_{3/2}$	1243878	0.0032		$^2P_{3/2}$	1406317	0.0118
$2s^22p^4(^1S)3d$	$^2D_{5/2}$	1291505	0.0139		$^2D_{5/2}$	1404870	0.0142
	$^2D_{3/2}$	1291798	0.0129		$^2D_{3/2}$	1403085	0.0083
$2s^22p^4(^3P)4s$	$^4P_{5/2}$	1323746	0.0834	$2s^22p^4(^1D)4d$	$^2G_{7/2}$	1441668	0.1595
	$^4P_{3/2}$	1326302	0.0659		$^2G_{9/2}$	1441758	0.1603
	$^4P_{1/2}$	1328637	0.0804		$^2S_{1/2}$	1444335	0.0075
	$^2P_{3/2}$	1329941	0.0414		$^2D_{5/2}$	1445003	0.0123
	$^2P_{1/2}$	1332772	0.0367		$^2P_{3/2}$	1445027	0.0068
$2s^22p^4(^1D)4s$	$^2D_{5/2}$	1371884	0.0520		$^2F_{7/2}$	1445156	0.2212
	$^2D_{3/2}$	1371913	0.0535		$^2D_{3/2}$	1445575	0.0103
$2s^22p^4(^3P)4d$	$^4D_{7/2}$	1392755	0.1500	$2s^22p^4(^1S)4d$.......	$^2D_{5/2}$	1497095	0.0668
	$^4D_{5/2}$	1392988	0.1576	$2s^22p^4(^3P)5d$	$^2D_{5/2}$	1497653	0.0068
	$^4F_{9/2}$	1396306	0.1762	$2s^22p^4(^1D)5d$	$^2S_{1/2}$	1538386	0.0102

[a] Lifetimes for the energy level obtained by the method described in § 2.

a least squares fit of the observed levels. More details of the calculations and the tables with the theoretical Hartree-Fock parameters and their fitting values can be found in Coutinho (1998). The energy level values were determined from the observed wavelengths by an interactive optimization procedure using the program ELCALC (Radziemski & Kaufman 1969), in which the individual wavelengths are weighted according to their uncertainties.

The energy levels adjusted by this method were used to optimize the electrostatic parameters by a least squares procedure, and finally these optimized parameters were used again to calculate the gf- and lifetimes values. This method produces gf-values that are in better agreement with line intensity observations and lifetimes values that are closer to the experimental ones.

We have presented oscillator strengths and lifetimes for all known electric dipole transitions in Si VI. The present work is part of an ongoing program, whose goal is to obtain weighted oscillator strength, gf, and lifetimes for elements of astrophysical importance. The work for Si III, Si V, and Si VII were concluded, Callegari & Trigueiros (1998), Trigueiros & Jupén (1996), and Coutinho & Trigueiros (1998). In this particular work on Si VI, the results are part of Coutinhos's M. Sc. thesis that is in preparation.

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