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INTRODUCTION

Resonance lines of silicon and sulfur ions are known to be present in the far ultraviolet spectrum of the solar corona, in the wavelength range 160 - 380A. Knowledge of the intensities of these lines is of importance for current studies of coronal conditons and abundances, such as those by Pottasch (1963), by Widing and Porter (1964), and by Jordan (1966). Garstang (1962) has made an intermediate coupling calculation of the oscillator strengths of such lines for Si X, using spectroscopic parameters obtained from observed energy levels. We have here computed oscillator strengths for the resonance lines of Si VI, VII, VIII, IX, X and S VIII, IX, X, XI, XII, using wave functions and energies obtained by use of the Hartree-Fock computer program of C. Froese (1963). Comparison of the results for Si X with Garstang's results for the same ion provides a desirable check on this ab initio calculation. The results for the other ions may be expected to have the same

degree of validity as those for Si X since they are calculated by the same procedure; however, possible configuration interactions have been neglected.*

Because of the importance of spin-spin and spin-other orbit interactions in the case of the configuration p^3, the diagonal elements of such interactions were included for every configuration, when present, to be complete and consistent.

CALCULATION OF INTERMEDIATE COUPLING

The transition arrays involved are given in Table 1:

TABLE 1

Ion	Ground Configuration	Excited Configuration
Si VI, S VIII	$2s^2\ 2p^5$	$2s\ 2p^6$
Si VII, S IX	$2s^2\ 2p^4$	$2s\ 2p^5$
Si VIII, S X	$2s^2\ 2p^3$	$2s\ 2p^4$
Si IX, S XI	$2s^2\ 2p^2$	$2s\ 2p^3$
Si X, S XII	$2s^2\ 2p$	$2s\ 2p^2$

* Dr. C. Froese has recently obtained some multiplet strengths of Si VIII and IX, taking configuration interaction into account (Bull. Astr. Inst. Netherland 19, 86 (1967)).

The line strength matrix $S^{1/2}$ for LS coupling was obtained for each of these arrays from the general tables of Shore and Menzel. The signs (phases) of the matrix elements were changed in some cases because the tables are constructed for transitions $p^n s$ ___ $p^{n-1}s^2$ rather than sp^n___ s^2p^{n-1} To ascertain the correct signs, basis functions were constructed for the configurations involved; these bases were also used to ascertain the changes in sign required in the spin-orbit matrices.

The transformation matrices A_i and B_i, which diagonalize the energies of the initial and final configuration array i, are required next. The energy matrix of each configuration was constructed by adding, to the matrix of electrostatic interaction, the appropriate spin-orbit matrix with signs established as noted above. Further, the diagonal elements of spin-spin interaction and spin-other orbit interaction were included, as given by Obi and Yanagawa; though only the major term in M^o, in these, was used (M^o is conveniently calculated by the Froese program).

The Froese program furnished values for the electrostatic energies and the spin-orbit parameters ζ_{2p}, required in the energy matrices. From the corresonding wave functions, radial integrals $I(n\ell, n'\ell') = \int_o^{oo} rP_{n\ell} P_{n'\ell'} dr$ were calculated

for use in the line strength matrix elements. The transformation to the intermediate coupling (IC) line strengths can then be made for each array:

$$S_{IC}^{1/2} = B\, S_{LS}^{1/2}\, \tilde{A}$$

The weighted oscillator strengths gf are given, for transitions $J \rightarrow J'$, by

$$gf = (3.0374 \times 10^{-6})\, \tilde{\upsilon}\, S(J',J)$$

where $\tilde{\upsilon}$ denotes the transition wavenumber in cm^{-1}.

DISCUSSION OF RESULTS:

Values of the quantity $\sigma^2 = 1/3\, [I(n\ell, n'\ell)]^2$ are given in Table 2:

TABLE 2

THE RADIAL PARAMETER σ^2

Array	σ^2	
	Si	S
$2s\ 2p^4$ ——— $2s\ 2p^5$	0.0835	0.0415
$2s\ 2p^3$ ——— $2s\ 2p^4$	0.0700	0.0550
$2s\ 2p^2$ ——— $2s\ 2p^3$	0.0724	0.0520
$2s\ 2p^2$ ——— $2s\ 2p^2$	0.0742	0.0491

The value $\sigma^2 = 0.0742$ for Si X agrees well with the value of 0.075 deduced by Garstang from Varsavsky's result. In comparing our results for Si X with those of Garstang, we have added 25% to Garstang's values, which were based on the Bates-Damgaard value $\sigma^2 = 0.060$. Table 3 compares the two sets of oscillator strengths for Si X and includes our results for S XII. The agreement for Si X is quite good. Because of the different methods of calculation it is difficult to say much about the differences which remain, except that at least a part of these must be due to the inclusion of the minor spin-spin and spin-other orbit interactions. The value 2.7×10^{-4} for the $^2P_{3/2} - {}^4P_{5/2}$ transition is somewhat greater than Garstang's value, though this intercombination line would still be unobservable in practice.

Tables 4,5,6,7 give oscillator strengths for the other silicon and sulfur ions. In these tables, for convenience in use, calculated wavelengths are listed in parentheses and observed wavelengths (Moore 1949) are listed without parentheses.

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TABLE 3

WEIGHTED OSCILLATOR STRENGTHS gf FOR $2s^2 2p - 2s^2 2$ TRANSITIONS IN Si X

Transition	Si X Garstang (adjusted)	Si X Present Calculation	S XII
$^2P^0_{1/2}$ —— $^4P_{1/2}$	3.6×10^{-5}	2.4×10^{-5}	5.1×10^{-5}
$^2P^0_{3/2}$ —— $^4P_{1/2}$	1.8×10^{-5}	1.2×10^{-5}	2.3×10^{-5}
$^2P^0_{1/2}$ —— $^4P_{3/2}$	2.5×10^{-5}	4.1×10^{-5}	8.3×10^{-5}
$^2P^0_{3/2}$ —— $^4P_{3/2}$	3.8×10^{-5}	2.0×10^{-6}	4×10^{-6}
$^2P^0_{3/6}$ —— $^4P_{5/2}$	1.6×10^{-5}	2.7×10^{-4}	5.8×10^{-4}
$^2P^0_{1/2}$ —— $^2D_{3/2}$	0.23	0.16	0.12
$^2P^0_{3/2}$ —— $^2D_{3/2}$	0.034	0.035	0.030
$^2P^0_{3/2}$ —— $^2D_{5/2}$	0.39	0.28	0.22
$^2P^0_{1/2}$ —— $^2S_{1/2}$	0.109	0.087	0.094
$^2P^0_{3/2}$ —— $^2S_{1/2}$	0.066	0.071	0.039
$^2P^0_{1/2}$ —— $^2P_{1/2}$	0.30	0.30	0.20
$^2P^0_{3/2}$ —— $^2P_{1/2}$	0.23	0.20	0.17
$^2P^0_{1/2}$ —— $^2P_{3/2}$	0.16	0.21	0.14
$^2P^0_{3/2}$ —— $^2P_{3/2}$	0.90	0.79	0.63

TABLE 4

WEIGHTED OSCILLATOR STRENGTHS gf FOR $2s^2\ 2p^2 - 2s2p^3$ TRANSITIONS IN Si IX AND S XI

Transition	Si IX			S XI	
	λ		gf	λ	gf
$^3P_2$ ——— $^3D_3$	350.0	(367.2)	0.42	(309.9)	0.35
$^3P_2$ ——— $^3D_2$	349.8	(367.2)	0.057	(310.3)	0.089
$^3P_2$ ——— $^3D_1$	350.0	(367.0)	0.0072	(309.8)	0.0074
$^3P_1$ ——— $^3D_2$	345.1	(362.0)	0.21	(303.4)	0.17
$^3P_1$ ——— $^3D_1$	345.0	(361.8)	0.082	(302.9)	0.073
$^3P_0$ ——— $^3D_1$	342.0	(358.7)	0.094	(298.3)	0.076
$^3P_2$ ——— $^3P_2$	296.2	(310.1)	0.24	(262.1)	0.18
$^3P_2$ ——— $^3P_1$	296.2	(309.6)	0.095	(261.0)	0.084
$^3P_1$ ——— $^3P_2$	292.8	(306.4)	0.068	(257.2)	0.11
$^3P_1$ ——— $^3P_1$	292.8	(305.8)	0.042	(256.1)	0.030
$^3P_1$ ——— $^3P_0$	292.8	(305.9)	0.072	(256.3)	0.062
$^3P_0$ ——— $^3P_1$	290.6	(303.6)	0.079	(252.8)	0.071
$^1D_2$ ——— $^1D_2$		(260.8)	1.26	(276.2)	0.84
$^1D_2$ ——— $^1P_2$		(230.4)	0.47	(236.7)	0 32
$^3P_2$ ——— $^3S_1$	227.0	(229.7)	0.61	(195.8)	0.50
$^3P_1$ ——— $^3S_1$	225.0	(227.6)	0.39	(193.0)	0.33
$^3P_0$ ——— $^3S_1$	223.7	(226.4)	0.13	(191.1)	0.11

TABLE 4 (CONTINUED)

Transition	Si IX		S XI	
	λ	gf	λ	gf
$^1S_0$ ——— $^1P_1$	(279.2)	0.31	(195.1)	0.32
$^3P_2$ ——— $^1D_2$	(231.2)	0.0079	(196.3)	0.018
$^3P_1$ ——— $^1D_2$	(229.1)	8×10^{-5}	(193.5)	2.3×10^{-4}
$^3P_2$ ——— $^1P_1$	(207.0)	0.011	(175.5)	0.024
$^3P_1$ ——— $^1P_1$	(205.3)	0.0017	(173.3)	0.0034
$^3P_0$ ——— $^1P_1$	(204.3)	0.0034	(171.7)	0.0089
$^1S_0$ ——— $^3D_1$	(678.0)	2.1×10^{-4}	(376.8)	8.8×10^{-4}
$^1S_0$ ——— $^3P_1$	(504.8)	5.6×10^{-5}	(307.0)	3.3×10^{-4}
$^3P_2$ ——— $^5S_2$	(280.0)	0.0041	(237.5)	0.0093
$^1P_1$ ——— $^3S_2$	(277.0)	0.0013	(233.5)	0.0045
$^1D_2$ ——— $^5S_2$	(324.8)	7×10^{-5}	(265.5)	3.4×10^{-4}
$^1D_2$ ——— $^3D_3$	(448.0)	0.0013	(570.5)	0.0019
$^1D_2$ ——— $^3D_2$	(448.2)	2.1×10^{-4}	(571.8)	6.0×10^{-4}
$^1D_2$ ——— $^3D_1$	(447.8)	1.9×10^{-4}	(570.1)	3.0×10^{-4}
$^1D_2$ ——— $^3P_2$	(365.8)	0.0028	(427.2)	0.0043
$^1D_2$ ——— $^3P_1$	(365.1)	3.2×10^{-4}	(424.3)	4.8×10^{-4}
$^1D_2$ ——— $^3S_1$	(258.9)	0.0085	(275.2)	0.014
$^1S_0$ ——— $^3S_1$	(322.2)	0.0024	(220.6)	0.0067

Table 5

Weighted Oscillator Strengths gf for $2s^2 2p^3 - 2s2p^4$ Transitions in Si VIII and S X

Transition	Si VIII			S X	
	λ		gf	λ	gf
$^4S_{3/2} - {}^4P_{1/2}$	314.3	(321.1)	0.13	(265.5)	0.125
$^4S_{3/2} - {}^4P_{3/2}$	316.2	(323.0)	0.26	(269.5)	0.25
$^4S_{3/2} - {}^4P_{5/2}$	319.8	(326.6)	0.39	(272.7)	0.37
$^2D_{3/2} - {}^2D_{3/2}$		(318.7)	0.38	(266.0)	0.36
$^2D_{3/2} - {}^2D_{5/2}$		(318.6)	0.026	(265.8)	0.017
$^2D_{5/2} - {}^2D_{3/2}$		(318.9)	0.045	(266.7)	0.046
$^2D_{5/2} - {}^2D_{5/2}$		(318.7)	0.56	(266.4)	0.53
$^2D_{3/2} - {}^2P_{1/2}$		(211.6)	0.54	(178.8)	0.38
$^2D_{3/2} - {}^2P_{3/2}$		(213.4)	0.057	(179.9)	0.035
$^2D_{5/2} - {}^2P_{3/2}$		(213.5)	0.88	(180.2)	0.82
$^2P_{1/2} - {}^2S_{1/2}$		(259.5)	0.13	(217.2)	0.14
$^2P_{3/2} - {}^2S_{1/2}$		(259.7)	0.20	(218.0)	0.15
$^2P_{1/2} - {}^2D_{3/2}$		(377.4)	0.096	(315.4)	0.092
$^2P_{3/2} - {}^2D_{3/2}$		(377.9)	0.0063	(317.0)	0.0018
$^2P_{3/2} - {}^2D_{5/2}$		(377.8)	0.18	(316.6)	0.18
$^2P_{1/2} - {}^2P_{1/2}$		(235.9)	0.15	(199.9)	0.12
$^2P_{1/2} - {}^2P_{3/2}$		(238.3)	0.085	(201.2)	0.078
$^2P_{3/2} - {}^2P_{1/2}$		(236.2)	0.077	(200.5)	0.20
$^2P_{3/2} - {}^2P_{3/2}$		(238.5)	0.48	(201.8)	0.46
$^2D_{3/2} - {}^2S_{1/2}$		(230.3)	1.6×10^{-4}	(192.6)	0.026

TABLE 5 (Continued)

Transition	Si VIII		S X	
	λ	gf	λ	gf
$^4S_{3/2} - {}^2D_{3/2}$	(258.3)	4×10^{-6}	(216.1)	7×10^{-6}
$^4S_{3/2} - {}^2D_{5/2}$	(258.2)	6.2×10^{-4}	(215.9)	1.7×10^{-4}
$^4S_{3/2} - {}^2P_{1/2}$	(183.2)	1.6×10^{-4}	(154.8)	5.2×10^{-4}
$^4S_{3/2} - {}^2P_{3/2}$	(184.5)	7.7×10^{-4}	(155.6)	0.0019
$^4S_{3/2} - {}^2S_{1/2}$	(197.0)	7.1×10^{-4}	(165.0)	0.0017
$^2D_{3/2} - {}^4P_{1/2}$	(420.0)	0	(345.2)	9×10^{-6}
$^2D_{3/2} - {}^4P_{3/2}$	(423.4)	4.5×10^{-5}	(352.0)	7.5×10^{-5}
$^2D_{5/2} - {}^4P_{5/2}$	(429.4)	5.1×10^{-5}	(357.5)	1.6×10^{-4}
$^2D_{5/2} - {}^4P_{3/2}$	(423.5)	4.5×10^{-5}	(353.1)	1.2×10^{-4}
$^2D_{5/2} - {}^4P_{5/2}$	(429.7)	4.6×10^{-4}	(358.6)	0.0012
$^2P_{1/2} - {}^4P_{1/2}$	(528.3)	4.1×10^{-5}	(433.3)	4.6×10^{-5}
$^2P_{1/2} - {}^4P_{3/2}$	(533.6)	2.5×10^{-5}	(444.0)	6.4×10^{-5}
$^2P_{3/2} - {}^4P_{1/2}$	(529.7)	2.4×10^{-4}	(436.1)	7.4×10^{-4}
$^2P_{3/2} - {}^4P_{3/2}$	(535.0)	2.1×10^{-4}	(447.0)	5.4×10^{-5}
$^2P_{3/2} - {}^4P_{5/2}$	(544.7)	1.2×10^{-5}	(455.8)	2.3×10^{-5}

TABLE 6

Weighted Oscillator Strengths gf for 2s 2p - 2s2p Transitions in Si VII and S IX

Transitions	Si VII			S IX	
	λ		gf	λ	gf
$^3P_2$ — $^3P_2$	273.1	(269.4)	0.70	(220.8)	0.58
$^3P_2$ — $^3P_1$	272.6	(270.7)	0.23	(222.6)	0.19
$^3P_1$ — $^3P_2$	276.1	(272.2)	0.23	(224.6)	0.19
$^3P_1$ — $^3P_1$	275.1	(273.5)	0.14	(226.4)	0.11
$^3P_1$ — $^3P_0$	274.2	(276.2)	0.18	(229.9)	0.15
$^3P_0$ — $^3P_1$	276.8	(274.6)	0.18	(227.8)	0.15
$^1D_2$ — $^1P_1$	217.8	(211.9)	1.19	(176.9)	1.00
$^1S_0$ — $^1P_1$	246.1	(248.5)	0.20	(207.8)	0.17
$^3P_2$ — $^1P_1$	197.6	(192.1)	0.0047	(159.9)	0.010
$^3P_1$ — $^1P_1$	199.2	(193.5)	5.3×10^{-5}	(161.8)	1.2×10^{-4}
$^3P_0$ — $^1P_1$	199.8	(194.1)	9.6×10^{-4}	(162.5)	0.0022
$^1D_2$ — $^3P_2$	313.3	(310.1)	0.0016	(254.8)	0.0034
$^1D_2$ — $^3P_1$	312.7	(311.8)	0.0014	(257.1)	0.0032
$^1S_0$ — $^3P_1$	374.5	(398.1)	4.7×10^{-4}	(327.9)	0.0011

TABLE 7

Weighted Oscillator Strengths gf for $2s^2 2p^5$ - $2s2p^6$ Transitions in Si VI and S VIII

Transition	Si VI			S VIII		
	λ		gf	λ		gf
$^2P_{1/2} - {}^2S_{1/2}$	249.1	(240.0)	0.23	202.7	(198.0)	0.20
$^2P_{3/2} - {}^2S_{1/2}$	246.0	(237.2)	0.45	198.6	(194.3)	0.38