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Hibbert, A.; Hansen, J.E.

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Transitions in Ar II

A Hibbert† and J E Hansen‡

† Department of Applied Mathematics and Theoretical Physics, The Queen's University of Belfast, Belfast BT7 1NN, UK

‡ van der Waals–Zeeman Laboratory, Valcknierstraat 65, NL-1018 XE, Amsterdam, The Netherlands

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Abstract. We present extensive configuration interaction (CI) calculations of oscillator strengths, transition probabilities and lifetimes of upper levels of all transitions in Ar II between the levels of $3s^23p^5$, $3s3p^6$, $3p^43d$, $3p^44s$ and $3p^44p$ states. The calculations incorporate the major correlation effects and in addition allow for the orbital functions (particularly $3p$) to be effectively different for different states. Some discrepancies with experimental energies remain, particularly those of levels with a $3p^4\ ^1S$ core. Prior to the calculation of the oscillator strengths, we 'fine-tune' the CI coefficients using experimental energies. Specifically, the final CI coefficients are determined following small adjustments to the diagonal Hamiltonian matrix elements so that the calculated eigenvalue differences agree with the corresponding experimental energy separations. This work describes in detail our previous calculations of quartet levels and extends the calculations to other symmetries. Comparison with recent, highly accurate cascade-free experiments shows close accord in all but a small number of transitions.

1. Introduction

An extensive analysis of the spectrum of Ar II was published some time ago by Minnhagen (1963) and in 1969 Wiese *et al* (1969) made the first extensive compilation of atomic transition probabilities for this ion. For the large majority of the 240 transitions considered, the uncertainties were estimated to be in the range from 25% to 50%. Given the importance of Ar plasmas for fundamental studies as well as in technical applications, many attempts have been made since then to improve the quality of the data. However, Schmoranzner *et al* (1986) have recently collected the available lifetime data for three quartet levels and shown that the spread still is so large that the accuracy of many of the later determinations is seriously open to question. A critical compilation of previous work has recently been published by Vujanović and Wiese (1992). They classify particularly the experimental work and conclude that really accurate data is limited to those methods in which either no cascades occur (because of selective excitation) or the effect of cascades is taken into account. The most successful experimental technique has been the beam-dye-laser method used by Ward *et al* (1985), Schmoranzner *et al* (1986) and Marger and Schmoranzner (1990). By this approach the experimental error bars for some $4p$ levels have been reduced to less than 1%. By exploiting this recent work, Vujanović and Wiese (1992) were able to provide recommended values for the lifetimes of $3p^44p$ and $3p^44d$ levels and the probabilities of transitions from these levels.

Prior to our recent work, limited to lifetimes of certain quartet levels (Hibbert and Hansen 1989), the only theoretical work to take configuration interaction into account was that of Luyken (1972). Even then, his values for transition probabilities calculated in length

and velocity forms differed by 30–40%. By extending the number of configurations and the flexibility of the radial functions, we (Hibbert and Hansen 1989) were able to achieve agreement between length and velocity forms to better than 5%. Moreover, the agreement between our calculations and the beam-dye-laser experiments was also better than 5%. In this paper, we report calculations, at the same level of sophistication as our previous partial results (Hibbert and Hansen 1989), of transition probabilities for all electric dipole transitions between levels arising from $3s^2 3p^5$, $3s 3p^6$ and $3s^2 3p^4 nl$ ($nl = 3d, 4s, 4p$). From the transition probabilities the lifetimes of these levels are deduced.

2. Method of calculation

We express the wavefunctions in terms of configuration interaction (CI) expansions:

$$\Psi(LSJ) = \sum_{i=1}^M a_i \Phi_i(\alpha_i LSJ) \quad (1)$$

where $\{\Phi_i\}$ are single-configuration functions and the expansions in general include summations over L and S . For a specific choice of $\{\Phi_i\}$, the expansion coefficients $\{a_i\}$ are the eigenvector components of the diagonalized Hamiltonian with matrix elements $H_{ij} = \langle \Phi_i | H | \Phi_j \rangle$. In this work, we take the Hamiltonian H to be the Schrödinger Hamiltonian plus the mass correction and Darwin terms, together with a modified spin-orbit term

$$H_{so} = \frac{1}{2} \alpha^2 \sum_{i=1}^N \frac{Z \zeta_i}{r_i^3} l_i \cdot s_i. \quad (2)$$

In (2), the sum is over the electrons and the parameters $\{\zeta_i\}$ depend on the l -value of the electrons involved in the interaction (Hibbert and Hansen 1989).

The ordered eigenvalues $\{E_i\}$ of the Hamiltonian matrix are upper bounds to the similarly ordered energy levels (Hylleraas and Undheim 1930, Perkins 1965):

$$E_i \geq E_i^{\text{exact}}. \quad (3)$$

Hence any of the eigenvalues may be used as the variational functional for optimization of the radial parts of the one-electron orbitals from which the $\{\Phi_i\}$ are constructed. We express these radial functions as sums of normalized Slater-type orbitals (STOs):

$$P_{nl}(r) = \sum_{j=1}^k c_{jnl} \chi_{jnl}(r) \quad (4)$$

where the STOs are of the form

$$\chi_{jnl}(r) = \left(\frac{(2\xi_{jnl})^{2I_{jnl}+1}}{(2I_{jnl})!} \right)^{1/2} r^{I_{jnl}} \exp(-\xi_{jnl}r). \quad (5)$$

The $\{I_{jnl}\}$, being integers, are kept fixed but the exponents $\{\xi_{jnl}\}$ and the coefficients $\{c_{jnl}\}$ may be treated as variational parameters in (3), subject to the orthonormality conditions:

$$\int_0^\infty P_{nl}(r) P_{n'l}(r) dr = \delta_{nn'} \quad l < n' \leq n. \quad (6)$$

Table 1. Method of determining the radial functions.

Orbital	Process of optimization	
1s, 2s, 2p, 3s	Hartree-Fock orbitals of $3p^4\ ^1D$ of Ar III (Clementi and Roetti (1974))	
3p	Exponents taken from the Hartree-Fock orbital of $3p^4\ ^1D$ of Ar III; coefficients reoptimized on $3p^4 4s\ ^4P$ of Ar II	
	Eigenvalue minimized	Configurations
3d	$3s3p^6\ ^2S$	$3s3p^6, 3s^23p^43d$
4s	$3p^4 4s\ ^4P$	$3p^4 4s$
4p	$3p^4 4p\ ^4D^o$	$3p^4 4p$
4d	$3p^4 3d\ ^4D$	$3p^4 3d, 3p^4 4d$
4f	$3p^4 3d\ ^4P$	$3p^4 4s, 3p^4 3d, 3p^4 4d, 3p^3 3d 4f$
5s	$3p^4 4p\ ^4D^o$	$3p^4 4p, 3p^3 4s 5s$
5p	$3p^4 4p\ ^4P^o$	$3p^4 4p, 3p^4 5p$
5d	$3p^4 3d\ ^4F$	$3p^4 3d, 3p^4 4d, 3p^4 5d$
5f	$3p^4 4p\ ^4D^o$	$3p^4 4p, 3p^4 4f, 3p^4 5f$
6s	$3p^4 4s\ ^4P$	$3p^4 4s, 3p^4 5s, 3p^4 6s,$ $3p^4 3d, 3p^4 4d, 3p^4 5d, 3s3p^5 4p$
6d	$3p^4 4s\ ^4P$	$3p^4 4s, 3p^4 5s, 3p^4 6s,$ $3p^4 3d, 3p^4 4d, 3p^4 5d, 3p^4 6d$

In this work we wish to construct wavefunctions for all $LSJ\pi$ symmetries of the states with electron occupancy $3s^2 3p^4 nl$ ($nl = 3d, 4s, 4p$) as well as $3s^2 3p^5$ and $3s3p^6$. Orbitals with the same label nl are not necessarily well represented by the same radial function in each state. This is particularly true for the 3p orbital, whose radial function for the $3s^2 3p^5$ state is rather different from that for, say, any of the $3s^2 3p^4 nl$ states. In order to use a single set of orthogonal orbitals, the configuration, and in fact term, dependence of the spectroscopic orbitals makes it necessary to include 'correcting' orbitals in addition to 'correlation' orbitals.

The calculations described here have been undertaken with the code CIV3 (Hibbert 1975, Glass and Hibbert 1978, Hibbert *et al* 1991). The process of optimizing the radial functions is summarized in table 1. For all the optimizations, only the non-relativistic (Schrödinger) equation was used. In determining the 1s, 2s, 2p, 3s and 3p functions, emphasis was placed on the $3p^4 nl$ states with corrections being made to the $3s^2 3p^5$ and $3s3p^6$ states using additional 'correcting' orbitals. However, the 3d function was chosen to give an accurate representation of the strong $3s3p^6-3s^2 3p^4 \overline{3d}$ correlation effect in the lowest 2S state (see Hibbert and Hansen 1987). The correlation orbital $\overline{3d}$, which we label simply as 3d in table 1, has a very different radial form from the spectroscopic 3d orbital of the $3p^4 3d$ states. Hence the 4d function in table 1 is optimized so that the spectroscopic 3d function associated with the $3p^4 3d\ ^4D$ term is a linear combination of our 3d and 4d functions. Our 5d orbital is optimized as a correcting orbital, to allow the orbital usually labelled 3d in the $3p^4 3d$ states to be different for 4D and 4F . The 4f orbital is a correlation orbital optimized to represent the $3p \rightarrow f$ correlation effect in the core, while 5f represent the equivalent $4p \rightarrow f$ correlation effect for the valence electron. All the other orbitals listed in table 1 were optimized to give a good representation of the valence electron in the excited states for the different LS symmetries. The optimized radial function parameters are listed in table 2.

We find that the fine structure of the spectroscopically pure states is quite well represented by taking, in (2), $\zeta_1 = 0.856$ and $\zeta_l = 0$ for $l \neq 1$.

The configurations included in the CI calculations for each parity are shown in table 3. They represent all the major internal and semi-internal correlation effects (Öksüz

Table 2. Radial function parameters.

nl	C_{jnl}	I_{jnl}	ξ_{jnl}	nl	C_{jnl}	I_{jnl}	ξ_{jnl}
1s	0.926 94	1	17.332 10	2p	-0.011 17	3	3.102 81
	0.058 91	1	25.455 00		0.004 97	3	2.011 93
	0.007 82	2	7.657 68		0.145 75	3	5.190 03
	0.017 65	2	15.623 20	3p	0.824 78	2	6.928 92
	0.000 90	3	3.237 31		0.087 03	2	13.042 40
	-0.000 47	3	2.296 92		0.530 23	3	3.102 81
	-0.003 17	3	6.726 86	4p	0.583 91	3	2.011 93
2s	-0.277 90	1	17.332 10		-0.074 28	3	5.190 03
	-0.008 62	1	25.455 00		-0.272 24	2	6.928 92
	0.816 64	2	7.657 68	5p	-0.025 06	2	13.042 40
	-0.127 59	2	15.623 20		0.744 05	4	0.995 10
	0.013 06	3	3.237 31		0.297 40	4	0.775 02
	-0.003 71	3	2.296 92	3d	-0.296 30	3	2.508 00
	0.331 25	3	6.726 86		0.082 76	2	7.360 60
3s	-0.094 80	1	17.332 10		4.629 07	4	0.861 89
	-0.001 41	1	25.455 00	4d	-4.686 80	4	1.000 00
	0.289 14	2	7.657 68		0.735 21	3	3.221 66
	-0.043 25	2	15.623 20		-0.403 55	2	3.473 69
	-0.640 52	3	3.237 31	5d	0.249 70	3	3.465 62
	-0.494 62	3	2.296 92		0.821 57	3	1.684 33
	0.216 65	3	6.726 86		0.216 25	3	2.817 41
4s	0.487 62	4	21.299 90	6d	0.300 37	3	1.891 60
	0.569 47	4	1.016 95		-1.104 59	4	0.964 72
	-0.384 57	3	2.931 16		0.067 82	4	0.570 20
	0.157 04	2	6.149 39	4f	1.039 94	3	2.088 74
	-0.042 15	1	14.064 49		-2.593 82	3	0.949 85
	1.133 28	5	1.364 91		2.232 89	4	0.810 30
	-2.125 95	4	2.019 60	5f	2.278 75	3	2.335 06
5s	1.487 29	3	2.884 30		-3.005 13	3	1.619 23
	-0.468 68	2	5.897 16		2.625 07	4	0.914 07
	0.113 37	1	14.178 86	6f	-1.967 83	4	0.622 43
	46.171 55	5	1.572 91		1.000 00	4	2.154 77
	6.824 48	4	0.972 73		0.522 16	4	2.573 22
	-54.303 02	4	1.274 50	7f	-1.044 69	5	1.224 76
	4.062 28	3	2.210 65				
6s	-0.693 99	2	3.222 19				
	0.044 87	1	18.167 18				

and Sinanoğlu 1969). In particular, for each basic $3s^2 3p^4 nl$ configuration, we include $3s 3p^5 n(l \pm 1)$, $3s^2 3p^3 3d n(l \pm 1)$, $3s^2 3p^3 4f nl$ and $3s^2 3p^3 5s n(l \pm 1)$. Hence for each $3p^4 nl$ state and also for $3s 3p^6$ the correlation thus introduced is equivalent. However, the $3s^2 3p^3 3d^2$ configuration, as well as being a one-electron change from $3s^2 3p^4 3d$, also corresponds to a $3p^2 \rightarrow 3d^2$ correlation effect in the ground state. This effect is not included for other states. Hence the ground state is relatively over-correlated, so that the calculated energy is too low compared with all the other states (see table 4).

Inaccuracies in the *ab initio* calculated energy differences correspond to inaccuracies in the CI coefficients in the wavefunctions (1). Both types of inaccuracy would lead to inaccuracies in the transition probabilities. We attempt to correct for these inaccuracies by making adjustments to the diagonal elements of the Hamiltonian matrix so that the eigenvalue differences are as close as possible to the observed energy separations (see

Table 3. Configurations used. All possible couplings of the angular momenta of the orbitals of the following configurations are included.

Odd parity	Even parity
$[1s^2 2s^2 2p^6]$	$[1s^2 2s^2 2p^6]$
	$3s^2 3p^5$
	$3s^2 3p^4 4p$
	$3s^2 3p^3 3d 4s$
	$3s^2 3p^4 4f$
	$3s^2 3p^4 5f$
	$3s^2 3p^3 3d^2$
	$3s^2 3p^3 3d 4d$
	$3s^2 3p^4 5p$
	$3s^2 3p^3 4s 5s$
	$3s 3p^5 3d$
	$3s 3p^5 4d$
	$3s 3p^5 4s$
	$3s 3p^6$
	$3s^2 3p^4 4s$
	$3s^2 3p^4 3d$
	$3s^2 3p^4 4d$
	$3s^2 3p^4 5d$
	$3s^2 3p^4 5s$
	$3s^2 3p^4 6s$
	$3s^2 3p^3 3d 4p$
	$3s^2 3p^3 3d 4f$
	$3s^2 3p^3 4s 4p$
	$3s^2 3p^3 4s 4f$
	$3s^2 3p^3 4d 4f$
	$3s^2 3p^3 5s 4p$
	$3s 3p^5 4p$
	$3s 3p^5 4f$
	$3s^2 3p^4 6d$

Brage and Hibbert (1989) for a discussion of this technique). In these calculations, the corrections needed are mostly small, and improve the accuracy of the fine-structure mixing of the different LS states, as well as ensuring that we are using the experimental values for the transition energies. The larger correction needed to adjust for the relative over-correlation of the ground state affects only the transition energies involving that state, since the ground state is spectroscopically pure in our calculation.

3. Results and discussion

3.1. Energies and wavefunctions

We show in table 4 our *ab initio* calculated energy levels and compare them with the experimental values of Minnhagen (1963). We have presented energy differences relative to $3p^4 3d^4 D_{7/2}$ rather than to the ground state since the latter, as just mentioned, is over-correlated in comparison with the others.

For those levels with a $3p^4(^3P)$ core, the error in the calculated energy is mostly less than 2000 cm^{-1} . For those with a $3p^4(^1D)$ core, the error is less than 4000 cm^{-1} , but for levels with a $3p^4(^1S)$ core, the error is greater—up to 10000 cm^{-1} . These larger errors for the other cores are due partly to our use of the same $3p$ orbital—optimized on the $3p^4(^3P)4s^4P$ state—and partly to the limited core correlation included: the correlation energy of $3p^4$ is different for different core LS symmetries. Prior to the calculation of the oscillator strengths, corrections are made to the diagonal Hamiltonian matrix elements so that the eigenvalue differences coincide with the experimental energy differences, as mentioned earlier.

In some of the levels, there is very strong CI mixing, mainly amongst states with the same total L and S . For each of the $4p$ levels, a single configuration state function clearly dominates. This is not true for all the $3d$ levels, where for some levels, particularly belonging to 2P and 2D , the assignment of a well defined label for the level is not clear-cut. An example of such strong mixing between $4s$ and $3d$ states occurs in the 2D levels and manifests itself in the curious fine-structure splittings shown in table 4. A more sensible pattern would occur if we were to reverse the $4s$ and $3d$ labels associated with the calculated

Table 4. Comparison of calculated and experimental energies (expressed in cm^{-1}).

Level		Calc. ^a	Expt ^b	Level		Calc. ^a	Expt ^b
3s3p ⁶	² S _{1/2}	-21 026	-23 606	3s ² 3p ⁵	² P _{3/2}	-144 475	-132 327
3p ⁴ (³ P)3d	⁴ D _{7/2}	0	0		² P _{1/2}	-143 062	-130 896
	⁴ D _{5/2}	168	154	3p ⁴ (³ P)4p	⁴ P _{5/2}	23 513	22 716
	⁴ D _{3/2}	320	303		⁴ P _{3/2}	23 845	23 024
	⁴ D _{1/2}	425	410		⁴ P _{1/2}	24 178	23 381
3p ⁴ (³ P)4s	⁴ P _{5/2}	2 908	1 914		⁴ D _{7/2}	25 945	24 907
	⁴ P _{3/2}	3 721	2 759		⁴ D _{5/2}	26 422	25 346
	⁴ P _{1/2}	4 223	3 274		⁴ D _{3/2}	26 882	25 840
	² P _{3/2}	7 144	5 916		⁴ D _{1/2}	27 135	26 101
3p ⁴ (³ P)3d	² P _{1/2}	8 124	6 931		² D _{5/2}	27 567	26 403
	⁴ F _{9/2}	10 327	9 859		² D _{3/2}	28 285	27 066
	⁴ F _{7/2}	10 855	10 250		² P _{1/2}	29 077	27 379
	⁴ F _{5/2}	11 245	10 640		² P _{3/2}	29 499	27 912
	⁴ F _{3/2}	11 511	10 904		⁴ S _{3/2}	30 164	28 721
	² P _{1/2}	15 214	12 383	3p ⁴ (¹ D)4p	² S _{1/2}	30 366	28 762
	² P _{3/2}	16 052	13 342		² F _{5/2}	42 020	38 074
	⁴ P _{1/2}	16 227	14 901		² F _{7/2}	42 112	38 203
	⁴ P _{3/2}	16 590	15 176		² P _{3/2}	43 660	39 887
	⁴ P _{5/2}	16 836	15 549		² P _{1/2}	44 182	40 489
3p ⁴ (¹ D)4s	² D _{3/2}	21 489	16 293		² D _{3/2}	45 343	41 021
	² D _{5/2}	19 227	16 515		² D _{5/2}	45 382	41 066
3p ⁴ (³ P)3d	² F _{7/2}	18 917	16 852	3p ⁴ (¹ S)4p	² P _{3/2}	67 583	59 647
	² F _{5/2}	19 933	17 820		² P _{1/2}	67 512	60 006
	² D _{3/2}	18 910	18 136				
	² D _{5/2}	21 884	18 760				
3p ⁴ (¹ D)3d	² G _{9/2}	24 678	21 854				
	² G _{7/2}	24 711	21 877				
	² F _{5/2}	34 916	30 972				
	² F _{7/2}	35 099	31 179				
3p ⁴ (¹ S)4s	² S _{1/2}	44 624	34 981				
3p ⁴ (¹ D)3d	² D _{5/2}	43 315	40 008				
	² D _{3/2}	43 847	40 502				
	² P _{3/2}	44 581	42 083				
	² P _{1/2}	44 849	42 494				
3p ⁴ (¹ S)3d	² D _{5/2}	56 444	47 265				
	² D _{3/2}	56 499	47 605				
3p ⁴ (¹ D)3d	² S _{1/2}	59 290	51 766				

^a This work.^b Minnhagen (1963).

²D_{3/2} energies. A similar interchange of the labels for (both levels of) these two ²D terms was proposed by Meyer *et al* (1991).

3.2. Oscillator strengths and lifetimes

The oscillator strengths of electric dipole transitions between all levels listed in table 4 are presented in table 5. The values for the 3s3p⁶ ²S—3s²3p⁵ ²P transitions are taken from the calculation reported in our earlier work (Hibbert and Hansen 1987) which was optimized for the excited ²S states. For transition wavelengths $\lambda > 2000$ Å, the air/vacuum factor (Edlén 1966) is included. The wavelengths shown are based on the (modified) theoretical energies and are used in the calculation of the transition probabilities. The calculated values are usually very close to the observed ones so that errors in the transition probabilities are due

Table 5. Oscillator strengths, transition probabilities (s^{-1}) and lifetimes (ns).

States						
Upper	Lower	$\lambda_{\text{calc}} (\text{\AA})$	f_l	f_u	A_l	A_u
$3p^4(^3P)4p^4P_{5/2}$	$3p^4(^3P)3d^4D_{3/2}$	4 460.58	0.0072	0.0077	1.612(6) [†]	1.725(6)
	$3p^4(^3P)4s^4P_{3/2}$	5 009.31	0.0866	0.0833	1.534(7)	1.475(7)
	$3p^4(^3P)4s^2P_{3/2}$	5 950.89	0.0001	0.0001	1.033(4)	1.137(4)
	$3p^4(^3P)3d^4F_{3/2}$	8 565.35	0.0000	0.0000	1.096(3)	1.242(3)
	$3p^4(^3P)3d^2P_{3/2}$	10 664.66	0.0001	0.0001	4.977(3)	4.992(3)
	$3p^4(^1D)4s^2D_{3/2}$	15 564.73	0.0000	0.0000	6.610(2)	1.002(3)
	$3p^4(^3P)3d^4P_{3/2}$	13 258.70	0.0064	0.0073	1.607(5)	1.849(5)
	$3p^4(^3P)3d^2D_{3/2}$	21 884.16	0.0000	0.0000	3.847(0)	3.751(0)
	$3p^4(^3P)3d^4D_{5/2}$	4 430.99	0.0346	0.0371	1.176(7)	1.260(7)
	$3p^4(^3P)4s^4P_{5/2}$	4 806.03	0.2707	0.2571	7.812(7)	7.420(7)
	$3p^4(^3P)3d^4F_{5/2}$	8 376.07	0.0002	0.0003	2.253(4)	2.541(4)
	$3p^4(^3P)3d^4P_{5/2}$	13 948.71	0.0069	0.0085	2.373(5)	2.920(5)
	$3p^4(^1D)4s^2D_{5/2}$	16 122.54	0.0000	0.0000	8.962(1)	9.185(1)
	$3p^4(^3P)3d^2F_{5/2}$	20 421.63	0.0000	0.0000	3.008(1)	4.918(0)
	$3p^4(^3P)3d^2D_{5/2}$	25 272.65	0.0000	0.0000	3.393(0)	7.806(1)
	$3p^4(^3P)3d^4D_{7/2}$	4 400.98	0.0697	0.0756	3.199(7)	3.470(7)
	$3p^4(^3P)3d^4F_{7/2}$	8 110.62	0.0009	0.0010	1.236(5)	1.386(5)
	$3p^4(^3P)3d^2F_{7/2}$	17 048.84	0.0001	0.0001	1.904(3)	1.409(3)
	$3p^4(^1D)3d^2G_{7/2}$	119 153.43	0.0000	0.0000	2.980(-2)	1.682(-1)
	Lifetime of upper state:				7.174(0)	7.213(0)
$3p^4(^3P)4p^4P_{3/2}$	$3s3p^6^2S_{1/2}$	2 143.88	0.0002	0.0002	1.271(5)	1.242(5)
	$3p^4(^3P)3d^4D_{1/2}$	4 420.92	0.0178	0.0191	3.037(6)	3.254(6)
	$3p^4(^3P)4s^4P_{1/2}$	5 062.05	0.1758	0.1692	2.287(7)	2.201(7)
	$3p^4(^3P)4s^2P_{1/2}$	6 212.25	0.0000	0.0000	9.342(1)	8.000(1)
	$3p^4(^3P)3d^2P_{1/2}$	9 394.97	0.0002	0.0002	9.183(3)	8.027(3)
	$3p^4(^3P)3d^4P_{1/2}$	12 307.38	0.0157	0.0176	3.460(5)	3.864(5)
	$3p^4(^3P)3d^4D_{3/2}$	4 400.08	0.0479	0.0515	1.650(7)	1.772(7)
	$3p^4(^3P)4s^4P_{3/2}$	4 933.20	0.0516	0.0489	1.414(7)	1.340(7)
	$3p^4(^3P)4s^2P_{3/2}$	5 843.79	0.0001	0.0001	2.488(4)	2.906(4)
	$3p^4(^3P)3d^4F_{3/2}$	8 345.20	0.0002	0.0002	2.005(4)	2.227(4)
	$3p^4(^3P)3d^2P_{3/2}$	10 325.28	0.0003	0.0003	1.768(4)	1.710(4)
	$3p^4(^1D)4s^2D_{3/2}$	14 852.72	0.0000	0.0000	1.137(2)	2.232(1)
	$3p^4(^3P)3d^4P_{3/2}$	12 738.52	0.0024	0.0028	9.986(4)	1.140(5)
	$3p^4(^3P)3d^2D_{3/2}$	20 502.30	0.0000	0.0000	9.523(1)	1.333(1)
	$3p^4(^3P)3d^4D_{5/2}$	4 371.33	0.0426	0.0463	2.230(7)	2.422(7)
	$3p^4(^3P)4s^4P_{5/2}$	4 735.92	0.1315	0.1262	5.863(7)	5.628(7)
	$3p^4(^3P)3d^4F_{5/2}$	8 165.42	0.0006	0.0007	9.044(4)	1.003(5)
	$3p^4(^3P)3d^4P_{5/2}$	13 374.16	0.0019	0.0025	1.047(5)	1.407(5)
	$3p^4(^1D)4s^2D_{5/2}$	15 359.84	0.0001	0.0001	5.222(3)	5.811(3)
	$3p^4(^3P)3d^2F_{5/2}$	19 213.19	0.0000	0.0000	5.744(1)	1.576(2)
	$3p^4(^3P)3d^2D_{5/2}$	23 447.57	0.0000	0.0000	8.179(1)	1.660(2)
	Lifetime of upper state:				7.230(0)	7.255(0)
$3p^4(^3P)4p^4P_{1/2}$	$3s3p^6^2S_{1/2}$	2 127.59	0.0001	0.0001	8.521(4)	8.429(4)
	$3p^4(^3P)3d^4D_{1/2}$	4 352.21	0.0656	0.0706	2.308(7)	2.485(7)
	$3p^4(^3P)4s^4P_{1/2}$	4 972.16	0.0388	0.0376	1.046(7)	1.013(7)
	$3p^4(^3P)4s^2P_{1/2}$	6 077.42	0.0005	0.0006	9.530(4)	1.135(5)
	$3p^4(^3P)3d^2P_{1/2}$	9 089.98	0.0001	0.0001	7.045(3)	5.049(3)
	$3p^4(^3P)3d^4P_{1/2}$	11 789.22	0.0029	0.0033	1.373(5)	1.566(5)
	$3p^4(^3P)3d^4D_{3/2}$	4 332.01	0.0258	0.0279	1.832(7)	1.984(7)
	$3p^4(^3P)4s^4P_{3/2}$	4 847.79	0.1505	0.1445	8.536(7)	8.197(7)
	$3p^4(^3P)4s^2P_{3/2}$	5 724.32	0.0001	0.0001	2.659(4)	2.794(4)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^3P)4p^4P_{1/2}$	$3p^4(^3P)3d^4F_{3/2}$	8 103.68	0.0002	0.0002	4.093(4)	4.526(4)
	$3p^4(^3P)3d^2P_{3/2}$	9 958.30	0.0001	0.0001	8.065(3)	1.315(4)
	$3p^4(^1D)4s^2D_{3/2}$	14 104.58	0.0003	0.0003	1.772(4)	2.326(4)
	$3p^4(^3P)3d^4P_{3/2}$	12 184.23	0.0053	0.0063	4.722(5)	5.644(5)
	$3p^4(^3P)3d^2D_{3/2}$	19 103.56	0.0000	0.0000	3.205(2)	1.362(2)
	Lifetime of upper state:				7.240(0)	7.256(0)
$3p^4(^3P)4p^4D_{7/2}$	$3p^4(^3P)3d^4D_{5/2}$	4 038.79	0.0037	0.0041	1.136(6)	1.264(6)
	$3p^4(^3P)4s^4P_{5/2}$	4 348.06	0.4490	0.4078	1.188(8)	1.079(8)
	$3p^4(^3P)3d^4F_{5/2}$	7 077.00	0.0007	0.0008	6.849(4)	7.749(4)
	$3p^4(^3P)3d^4P_{5/2}$	10 683.05	0.0056	0.0053	2.465(5)	2.313(5)
	$3p^4(^1D)4s^2D_{5/2}$	11 913.58	0.0000	0.0000	5.332(2)	8.602(2)
	$3p^4(^3P)3d^2F_{5/2}$	14 107.80	0.0000	0.0000	4.587(0)	1.296(1)
	$3p^4(^3P)3d^2D_{5/2}$	16 264.53	0.0000	0.0000	1.385(1)	7.563(1)
	$3p^4(^3P)3d^4D_{7/2}$	4 013.84	0.0265	0.0282	1.098(7)	1.168(7)
	$3p^4(^3P)3d^4F_{7/2}$	6 886.56	0.0113	0.0128	1.594(6)	1.793(6)
	$3p^4(^3P)3d^2F_{7/2}$	12 411.56	0.0000	0.0000	2.545(2)	1.521(2)
	$3p^4(^1D)3d^2G_{7/2}$	32 995.07	0.0000	0.0000	1.327(-3)	8.524(-1)
	$3p^4(^3P)3d^4F_{9/2}$	6 643.70	0.0903	0.0984	1.705(7)	1.858(7)
	$3p^4(^1D)3d^2G_{9/2}$	32 751.45	0.0000	0.0000	3.611(0)	2.695(1)
	Lifetime of upper state:				6.673(0)	7.066(0)
$3p^4(^3P)4p^4D_{5/2}$	$3p^4(^3P)3d^4D_{3/2}$	3 992.04	0.0056	0.0060	1.558(6)	1.674(6)
	$3p^4(^3P)4s^4P_{3/2}$	4 425.98	0.3765	0.3470	8.542(7)	7.872(7)
	$3p^4(^3P)4s^2P_{3/2}$	5 145.30	0.0439	0.0442	7.376(6)	7.412(6)
	$3p^4(^3P)3d^4F_{3/2}$	6 990.11	0.0013	0.0014	1.181(5)	1.322(5)
	$3p^4(^3P)3d^2P_{3/2}$	8 327.96	0.0013	0.0010	8.559(4)	6.283(4)
	$3p^4(^1D)4s^2D_{3/2}$	11 042.70	0.0000	0.0001	8.635(-1)	2.033(3)
	$3p^4(^3P)3d^4P_{3/2}$	9 829.76	0.0026	0.0023	1.189(5)	1.068(5)
	$3p^4(^3P)3d^2D_{3/2}$	13 887.96	0.0001	0.0001	1.820(3)	2.312(3)
	$3p^4(^3P)3d^4D_{5/2}$	3 968.35	0.0119	0.0124	5.055(6)	5.245(6)
	$3p^4(^3P)4s^4P_{5/2}$	4 266.53	0.0501	0.0455	1.836(7)	1.666(7)
	$3p^4(^3P)3d^4F_{5/2}$	6 863.53	0.0169	0.0189	2.398(6)	2.677(6)
	$3p^4(^3P)3d^4P_{5/2}$	10 203.99	0.0026	0.0026	1.640(5)	1.662(5)
	$3p^4(^1D)4s^2D_{5/2}$	11 320.58	0.0009	0.0002	4.567(4)	1.003(4)
	$3p^4(^3P)3d^2F_{5/2}$	13 284.21	0.0005	0.0005	1.883(4)	1.840(4)
	$3p^4(^3P)3d^2D_{5/2}$	15 179.54	0.0003	0.0002	9.294(3)	4.578(3)
	$3p^4(^3P)3d^4D_{7/2}$	3 944.27	0.0070	0.0075	4.018(6)	4.294(6)
	$3p^4(^3P)3d^4F_{7/2}$	6 684.27	0.0662	0.0739	1.318(7)	1.469(7)
	$3p^4(^3P)3d^2F_{7/2}$	11 769.60	0.0096	0.0079	6.176(5)	5.098(5)
	$3p^4(^1D)3d^2G_{7/2}$	28 816.64	0.0000	0.0000	2.397(2)	1.104(2)
	Lifetime of upper state:				7.218(0)	7.553(0)
$3p^4(^3P)4p^4D_{3/2}$	$3s3p^6^2S_{1/2}$	2 021.75	0.0000	0.0000	1.984(4)	1.832(4)
	$3p^4(^3P)3d^4D_{1/2}$	3 931.23	0.0093	0.0099	2.011(6)	2.129(6)
	$3p^4(^3P)4s^4P_{1/2}$	4 430.18	0.3303	0.3037	5.609(7)	5.157(7)
	$3p^4(^3P)4s^2P_{1/2}$	5 286.87	0.0110	0.0114	1.311(6)	1.354(6)
	$3p^4(^3P)3d^2P_{1/2}$	7 428.57	0.0008	0.0007	5.049(4)	4.052(4)
	$3p^4(^3P)3d^4P_{1/2}$	9 138.47	0.0020	0.0018	8.184(4)	7.034(4)
	$3p^4(^3P)3d^4D_{3/2}$	3 914.78	0.0079	0.0081	3.442(6)	3.540(6)
	$3p^4(^3P)4s^4P_{3/2}$	4 331.22	0.1537	0.1405	5.462(7)	4.991(7)
	$3p^4(^3P)4s^2P_{3/2}$	5 017.62	0.0021	0.0022	5.640(5)	5.785(5)
	$3p^4(^3P)3d^4F_{3/2}$	6 756.53	0.0225	0.0250	3.288(6)	3.653(6)
	$3p^4(^3P)3d^2P_{3/2}$	7 998.53	0.0000	0.0000	2.125(3)	2.484(3)

Table S. (continued)

States		$\lambda_{\text{calc}} (\text{\AA})$	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^3P)4p^4D_{3/2}$	$3p^4(^1D)4s^2D_{3/2}$	10 470.86	0.0008	0.0006	4.849(4)	3.600(4)
	$3p^4(^3P)3d^4P_{3/2}$	9 374.25	0.0041	0.0040	3.072(5)	3.026(5)
	$3p^4(^3P)3d^2D_{3/2}$	12 995.76	0.0002	0.0001	8.813(3)	4.905(3)
	$3p^4(^3P)3d^4D_{5/2}$	3 891.97	0.0102	0.0108	6.753(6)	7.145(6)
	$3p^4(^3P)4s^4P_{5/2}$	4 178.37	0.0025	0.0022	1.432(6)	1.253(6)
	$3p^4(^3P)3d^4F_{5/2}$	6 638.20	0.0643	0.0715	1.461(7)	1.622(7)
	$3p^4(^3P)3d^4P_{5/2}$	9 713.79	0.0003	0.0003	3.007(4)	3.319(4)
	$3p^4(^1D)4s^2D_{5/2}$	10 720.64	0.0004	0.0005	3.746(4)	4.762(4)
	$3p^4(^3P)3d^2F_{5/2}$	12 465.26	0.0023	0.0017	1.457(5)	1.122(5)
	$3p^4(^3P)3d^2D_{5/2}$	14 119.57	0.0000	0.0000	1.031(3)	1.442(3)
	Lifetime of upper state:				6.903(0)	7.245(0)
$3p^4(^3P)4p^4D_{1/2}$	$3s3p^6^2S_{1/2}$	2 011.16	0.0001	0.0000	9.669(4)	8.707(4)
	$3p^4(^3P)3d^4D_{1/2}$	3 891.39	0.0108	0.0112	4.735(6)	4.912(6)
	$3p^4(^3P)4s^4P_{1/2}$	4 379.65	0.2925	0.2682	1.017(8)	9.322(7)
	$3p^4(^3P)4s^2P_{1/2}$	5 215.12	0.0002	0.0003	5.988(4)	7.148(4)
	$3p^4(^3P)3d^2P_{1/2}$	7 287.57	0.0001	0.0001	1.452(4)	1.311(4)
	$3p^4(^3P)3d^4P_{1/2}$	8 926.03	0.0048	0.0045	4.015(5)	3.760(5)
	$3p^4(^3P)3d^4D_{3/2}$	3 875.27	0.0090	0.0095	8.018(6)	8.427(6)
	$3p^4(^3P)4s^4P_{3/2}$	4 282.90	0.0180	0.0163	1.307(7)	1.184(7)
	$3p^4(^3P)4s^2P_{3/2}$	4 952.89	0.0004	0.0004	2.071(5)	2.092(5)
	$3p^4(^3P)3d^4F_{3/2}$	6 639.69	0.0624	0.0692	1.886(7)	2.092(7)
	$3p^4(^3P)3d^2P_{3/2}$	7 835.31	0.0000	0.0000	7.428(3)	6.779(3)
	$3p^4(^1D)4s^2D_{3/2}$	10 192.90	0.0004	0.0005	4.709(4)	5.928(4)
	$3p^4(^3P)3d^4P_{3/2}$	9 150.83	0.0010	0.0010	1.592(5)	1.614(5)
	$3p^4(^3P)3d^2D_{3/2}$	12 570.30	0.0001	0.0001	8.872(3)	8.263(3)
	Lifetime of upper state:				6.785(0)	7.127(0)
$3p^4(^3P)4p^2D_{5/2}$	$3p^4(^3P)3d^4D_{3/2}$	3 830.39	0.0010	0.0011	2.978(5)	3.309(5)
	$3p^4(^3P)4s^4P_{3/2}$	4 228.16	0.0382	0.0344	9.507(6)	8.544(6)
	$3p^4(^3P)4s^2P_{3/2}$	4 879.88	0.4345	0.4226	8.109(7)	7.887(7)
	$3p^4(^3P)3d^4F_{3/2}$	6 509.13	0.0003	0.0003	2.575(4)	2.978(4)
	$3p^4(^3P)3d^2P_{3/2}$	7 654.01	0.0040	0.0029	3.065(5)	2.237(5)
	$3p^4(^1D)4s^2D_{3/2}$	9 888.41	0.0001	0.0000	6.741(3)	4.079(1)
	$3p^4(^3P)3d^4P_{3/2}$	8 904.50	0.0011	0.0010	6.019(4)	5.783(4)
	$3p^4(^3P)3d^2D_{3/2}$	12 110.09	0.0004	0.0005	1.256(4)	1.387(4)
	$3p^4(^3P)3d^4D_{5/2}$	3 808.58	0.0015	0.0016	6.798(5)	7.369(5)
	$3p^4(^3P)4s^4P_{5/2}$	4 082.37	0.0064	0.0055	2.544(6)	2.221(6)
	$3p^4(^3P)3d^4F_{5/2}$	6 399.24	0.0032	0.0036	5.128(5)	5.917(5)
	$3p^4(^3P)3d^4P_{5/2}$	9 210.30	0.0004	0.0005	3.479(4)	4.054(4)
	$3p^4(^1D)4s^2D_{5/2}$	10 110.65	0.0057	0.0019	3.705(5)	1.265(5)
	$3p^4(^3P)3d^2F_{5/2}$	11 648.16	0.0036	0.0035	1.773(5)	1.739(5)
	$3p^4(^3P)3d^2D_{5/2}$	13 080.23	0.0019	0.0011	7.546(4)	4.287(4)
	$3p^4(^3P)3d^4D_{7/2}$	3 786.39	0.0019	0.0020	1.178(6)	1.267(6)
	$3p^4(^3P)3d^4F_{7/2}$	6 243.13	0.0108	0.0124	2.459(6)	2.825(6)
	$3p^4(^3P)3d^2F_{7/2}$	10 467.30	0.0628	0.0555	5.095(6)	4.501(6)
	$3p^4(^1D)3d^2G_{7/2}$	22 087.12	0.0001	0.0000	2.314(3)	9.845(2)
	Lifetime of upper state:				9.575(0)	9.940(0)
$3p^4(^3P)4p^2D_{3/2}$	$3s3p^6^2S_{1/2}$	1 973.48	0.0008	0.0009	7.113(5)	7.264(5)
	$3p^4(^3P)3d^4D_{1/2}$	3 750.47	0.0008	0.0009	1.948(5)	2.123(5)
	$3p^4(^3P)4s^4P_{1/2}$	4 201.95	0.0100	0.0090	1.880(6)	1.691(6)
	$3p^4(^3P)4s^2P_{1/2}$	4 965.10	0.2655	0.2617	3.590(7)	3.538(7)
	$3p^4(^3P)3d^2P_{1/2}$	6 808.49	0.0140	0.0120	1.008(6)	8.620(5)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_v	A_l	A_v
Upper	Lower					
$3p^4(^3P)4p^2D_{3/2}$	$3p^4(^3P)3d^4P_{1/2}$	8217.77	0.0009	0.0009	4.662(4)	4.642(4)
	$3p^4(^3P)3d^4D_{3/2}$	3735.49	0.0005	0.0006	2.573(5)	2.886(5)
	$3p^4(^3P)4s^4P_{3/2}$	4112.82	0.0023	0.0019	8.913(5)	7.457(5)
	$3p^4(^3P)4s^2P_{3/2}$	4726.84	0.1741	0.1700	5.194(7)	5.071(7)
	$3p^4(^3P)3d^4F_{3/2}$	6239.67	0.0014	0.0016	2.394(5)	2.775(5)
	$3p^4(^3P)3d^2P_{3/2}$	7284.23	0.0021	0.0019	2.670(5)	2.360(5)
	$3p^4(^1D)4s^2D_{3/2}$	9279.61	0.0100	0.0067	7.735(5)	5.168(5)
	$3p^4(^3P)3d^4P_{3/2}$	8407.93	0.0001	0.0001	1.313(4)	8.949(3)
	$3p^4(^3P)3d^2D_{3/2}$	11209.74	0.0050	0.0035	2.631(5)	1.872(5)
	$3p^4(^3P)3d^4D_{5/2}$	3714.75	0.0003	0.0003	2.089(5)	2.209(5)
	$3p^4(^3P)4s^4P_{5/2}$	3974.75	0.0009	0.0008	5.532(5)	4.879(5)
	$3p^4(^3P)3d^4F_{5/2}$	6138.61	0.0033	0.0037	8.682(5)	9.918(5)
	$3p^4(^3P)3d^4P_{5/2}$	8680.07	0.0001	0.0001	1.996(4)	1.832(4)
	$3p^4(^1D)4s^2D_{5/2}$	9475.26	0.0124	0.0143	1.382(6)	1.592(6)
	$3p^4(^3P)3d^2F_{5/2}$	10812.81	0.0459	0.0386	3.930(6)	3.301(6)
	$3p^4(^3P)3d^2D_{5/2}$	12036.06	0.0005	0.0009	3.469(4)	6.032(4)
	Lifetime of upper state:				9.864(0)	1.015(1)
$3p^4(^3P)4p^2P_{1/2}$	$3s3p^6^2S_{1/2}$	1961.38	0.0033	0.0032	5.688(6)	5.491(6)
	$3p^4(^3P)3d^4D_{1/2}$	3707.01	0.0009	0.0009	4.249(5)	4.437(5)
	$3p^4(^3P)4s^4P_{1/2}$	4147.48	0.0008	0.0007	3.089(5)	2.529(5)
	$3p^4(^3P)4s^2P_{1/2}$	4889.17	0.0900	0.0936	2.510(7)	2.610(7)
	$3p^4(^3P)3d^2P_{1/2}$	6666.62	0.0323	0.0290	4.850(6)	4.355(6)
	$3p^4(^3P)3d^4P_{1/2}$	8011.99	0.0000	0.0000	6.868(2)	1.147(3)
	$3p^4(^3P)3d^4D_{3/2}$	3692.35	0.0000	0.0000	3.187(3)	4.484(3)
	$3p^4(^3P)4s^4P_{3/2}$	4060.58	0.0002	0.0001	1.263(5)	1.091(5)
	$3p^4(^3P)4s^2P_{3/2}$	4658.02	0.1104	0.1037	6.787(7)	6.373(7)
	$3p^4(^3P)3d^4F_{3/2}$	6120.31	0.0010	0.0011	3.535(5)	3.756(5)
	$3p^4(^3P)3d^2P_{3/2}$	7121.97	0.0009	0.0007	2.485(5)	1.740(5)
	$3p^4(^1D)4s^2D_{3/2}$	9018.07	0.0337	0.0373	5.517(6)	6.109(6)
	$3p^4(^3P)3d^4P_{3/2}$	8192.50	0.0002	0.0002	4.347(4)	4.555(4)
	$3p^4(^3P)3d^2D_{3/2}$	10830.04	0.0051	0.0040	5.771(5)	4.559(5)
	Lifetime of upper state:				9.000(0)	9.290(0)
$3p^4(^3P)4p^2P_{3/2}$	$3s3p^6^2S_{1/2}$	1941.07	0.0052	0.0051	4.633(6)	4.484(6)
	$3p^4(^3P)3d^4D_{1/2}$	3635.11	0.0000	0.0000	1.021(3)	1.383(3)
	$3p^4(^3P)4s^4P_{1/2}$	4057.68	0.0000	0.0000	5.662(0)	3.915(2)
	$3p^4(^3P)4s^2P_{1/2}$	4764.87	0.3512	0.3405	5.156(7)	5.000(7)
	$3p^4(^3P)3d^2P_{1/2}$	6437.63	0.0013	0.0012	1.023(5)	1.003(5)
	$3p^4(^3P)3d^4P_{1/2}$	7683.40	0.0006	0.0007	3.307(4)	3.694(4)
	$3p^4(^3P)3d^4D_{3/2}$	3621.01	0.0001	0.0001	3.860(4)	4.368(4)
	$3p^4(^3P)4s^4P_{3/2}$	3974.47	0.0023	0.0021	9.659(5)	9.049(5)
	$3p^4(^3P)4s^2P_{3/2}$	4545.06	0.1274	0.1224	4.110(7)	3.952(7)
	$3p^4(^3P)3d^4F_{3/2}$	5926.76	0.0000	0.0000	1.102(3)	1.530(3)
	$3p^4(^3P)3d^2P_{3/2}$	6861.24	0.0196	0.0180	2.782(6)	2.551(6)
	$3p^4(^1D)4s^2D_{3/2}$	8604.06	0.0032	0.0053	2.887(5)	4.778(5)
	$3p^4(^3P)3d^4P_{3/2}$	7849.38	0.0010	0.0009	1.074(5)	9.819(4)
	$3p^4(^3P)3d^2D_{3/2}$	10238.41	0.0000	0.0000	1.752(1)	5.212(2)
	$3p^4(^3P)3d^4D_{5/2}$	3601.51	0.0001	0.0002	1.086(5)	1.249(5)
	$3p^4(^3P)4s^4P_{5/2}$	3845.39	0.0013	0.0012	8.794(5)	8.048(5)
	$3p^4(^3P)3d^4F_{5/2}$	5835.52	0.0000	0.0000	6.876(2)	1.054(3)
	$3p^4(^3P)3d^4P_{5/2}$	8086.05	0.0002	0.0002	3.120(4)	2.450(4)
	$3p^4(^1D)4s^2D_{5/2}$	8771.83	0.0429	0.0443	5.579(6)	5.756(6)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^3P)4p^2P_{3/2}$	$3p^4(^3P)3d^2F_{5/2}$	9 906.27	0.0172	0.0166	1.748(6)	1.686(6)
	$3p^4(^3P)3d^2D_{5/2}$	10 923.36	0.0062	0.0021	5.215(5)	1.781(5)
Lifetime of upper state:					9.052(0)	9.364(0)
$3p^4(^3P)4p^4S_{3/2}$	$3s3p^6^2S_{1/2}$	1 911.06	0.0002	0.0002	1.798(5)	1.498(5)
	$3p^4(^3P)3d^4D_{1/2}$	3 531.18	0.0001	0.0001	2.855(4)	3.155(4)
	$3p^4(^3P)4s^4P_{1/2}$	3 928.62	0.1428	0.1364	3.084(7)	2.945(7)
	$3p^4(^3P)4s^2P_{1/2}$	4 587.88	0.0010	0.0009	1.515(5)	1.484(5)
	$3p^4(^3P)3d^2P_{1/2}$	6 118.72	0.0006	0.0006	5.583(4)	5.201(4)
	$3p^4(^3P)3d^4P_{1/2}$	7 233.54	0.0626	0.0611	3.987(6)	3.896(6)
	$3p^4(^3P)3d^4D_{3/2}$	3 517.90	0.0004	0.0004	1.977(5)	2.172(5)
	$3p^4(^3P)4s^4P_{3/2}$	3 850.60	0.1127	0.1075	5.064(7)	4.832(7)
	$3p^4(^3P)4s^2P_{3/2}$	4 383.74	0.0028	0.0027	9.652(5)	9.441(5)
	$3p^4(^3P)3d^4F_{3/2}$	5 655.39	0.0000	0.0000	5.031(2)	5.821(2)
	$3p^4(^3P)3d^2P_{3/2}$	6 500.24	0.0024	0.0023	3.773(5)	3.651(5)
	$3p^4(^1D)4s^2D_{3/2}$	8 043.73	0.0003	0.0004	3.206(4)	4.152(4)
	$3p^4(^3P)3d^4P_{3/2}$	7 380.48	0.0623	0.0613	7.623(6)	7.507(6)
	$3p^4(^3P)3d^2D_{3/2}$	9 454.88	0.0000	0.0000	2.911(3)	3.515(3)
	$3p^4(^3P)3d^4D_{5/2}$	3 499.47	0.0006	0.0006	4.662(5)	5.061(5)
	$3p^4(^3P)4s^4P_{5/2}$	3 729.31	0.0842	0.0800	6.057(7)	5.755(7)
	$3p^4(^3P)3d^4F_{5/2}$	5 572.25	0.0000	0.0000	2.119(3)	2.449(3)
	$3p^4(^3P)3d^4P_{5/2}$	7 589.34	0.0689	0.0688	1.197(7)	1.195(7)
	$3p^4(^1D)4s^2D_{5/2}$	8 190.32	0.0004	0.0005	6.298(4)	7.142(4)
	$3p^4(^3P)3d^2F_{5/2}$	9 170.93	0.0000	0.0000	7.291(0)	4.888(-1)
	$3p^4(^3P)3d^2D_{5/2}$	10 036.04	0.0001	0.0000	6.142(3)	4.402(3)
Lifetime of upper state:					5.947(0)	6.203(0)
$3p^4(^3P)4p^2S_{1/2}$	$3s3p^6^2S_{1/2}$	1 909.57	0.0003	0.0003	5.830(5)	5.993(5)
	$3p^4(^3P)3d^4D_{1/2}$	3 526.12	0.0000	0.0000	7.311(3)	5.580(3)
	$3p^4(^3P)4s^4P_{1/2}$	3 922.35	0.0001	0.0001	4.801(4)	4.095(4)
	$3p^4(^3P)4s^2P_{1/2}$	4 579.33	0.2107	0.1961	6.698(7)	6.235(7)
	$3p^4(^3P)3d^2P_{1/2}$	6 103.53	0.0211	0.0199	3.773(6)	3.567(6)
	$3p^4(^3P)3d^4P_{1/2}$	7 212.32	0.0001	0.0001	1.531(4)	1.564(4)
	$3p^4(^3P)3d^4D_{3/2}$	3 512.87	0.0000	0.0000	1.994(4)	1.833(4)
	$3p^4(^3P)4s^4P_{3/2}$	3 844.57	0.0003	0.0002	2.777(5)	2.085(5)
	$3p^4(^3P)4s^2P_{3/2}$	4 375.94	0.0459	0.0385	3.196(7)	2.682(7)
	$3p^4(^3P)3d^4F_{3/2}$	5 642.41	0.0000	0.0000	8.591(3)	9.108(3)
	$3p^4(^3P)3d^2P_{3/2}$	6 483.10	0.0367	0.0323	1.165(7)	1.025(7)
	$3p^4(^1D)4s^2D_{3/2}$	8 017.50	0.0096	0.0107	1.982(6)	2.223(6)
	$3p^4(^3P)3d^4P_{3/2}$	7 358.39	0.0012	0.0011	2.988(5)	2.654(5)
	$3p^4(^3P)3d^2D_{3/2}$	9 418.47	0.0007	0.0006	1.111(5)	9.059(4)
Lifetime of upper state:					8.495(0)	9.393(0)
$3p^4(^1D)4p^2F_{5/2}$	$3p^4(^3P)3d^4D_{3/2}$	2 646.80	0.0000	0.0000	3.905(3)	1.909(3)
	$3p^4(^3P)4s^4P_{3/2}$	2 830.83	0.0000	0.0000	1.548(2)	6.640(1)
	$3p^4(^3P)4s^2P_{3/2}$	3 108.80	0.0001	0.0000	4.149(4)	2.003(4)
	$3p^4(^3P)3d^4F_{3/2}$	3 698.59	0.0000	0.0000	3.349(3)	2.053(3)
	$3p^4(^3P)3d^2P_{3/2}$	4 042.19	0.0024	0.0020	6.409(5)	5.373(5)
	$3p^4(^1D)4s^2D_{3/2}$	4 589.89	0.3325	0.3154	7.015(7)	6.654(7)
	$3p^4(^3P)3d^4P_{3/2}$	4 366.00	0.0033	0.0027	7.605(5)	6.268(5)
	$3p^4(^3P)3d^2D_{3/2}$	5 017.13	0.1180	0.1001	2.084(7)	1.769(7)
	$3p^4(^3P)3d^4D_{5/2}$	2 636.35	0.0000	0.0000	9.987(3)	9.497(3)
	$3p^4(^3P)4s^4P_{5/2}$	2 764.72	0.0000	0.0000	1.310(3)	8.697(2)
	$3p^4(^3P)3d^4F_{5/2}$	3 662.85	0.0000	0.0000	2.352(3)	2.431(3)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^1D)4p\ ^2F_{5/2}$	$3p^4(^3P)3d\ ^4P_{5/2}$	4 438.25	0.0000	0.0000	1.666(2)	1.237(2)
	$3p^4(^1D)4s\ ^2D_{5/2}$	4 637.25	0.0173	0.0168	5.375(6)	5.217(6)
	$3p^4(^3P)3d\ ^2F_{5/2}$	4 936.08	0.0004	0.0002	1.029(5)	4.589(4)
	$3p^4(^3P)3d\ ^2D_{5/2}$	5 176.24	0.0106	0.0099	2.643(6)	2.472(6)
	$3p^4(^1D)3d\ ^2F_{5/2}$	14 077.65	0.0158	0.0137	5.311(5)	4.600(5)
	$3p^4(^3P)3d\ ^4D_{7/2}$	2 625.70	0.0000	0.0000	1.133(3)	1.198(3)
	$3p^4(^3P)3d\ ^4F_{7/2}$	3 611.16	0.0000	0.0000	2.660(3)	2.303(3)
	$3p^4(^3P)3d\ ^2F_{7/2}$	4 710.82	0.0008	0.0008	3.181(5)	3.275(5)
	$3p^4(^1D)3d\ ^2G_{7/2}$	6 172.30	0.0905	0.0945	2.112(7)	2.205(7)
	$3p^4(^1D)3d\ ^2F_{7/2}$	14 500.15	0.0007	0.0007	3.093(4)	2.963(4)
	Lifetime of upper state:				8.158(0)	8.618(0)
$3p^4(^1D)4p\ ^2F_{7/2}$	$3p^4(^3P)3d\ ^4D_{5/2}$	2 627.39	0.0000	0.0000	2.097(3)	7.091(2)
	$3p^4(^3P)4s\ ^4P_{5/2}$	2 754.87	0.0000	0.0000	2.546(4)	1.703(4)
	$3p^4(^3P)3d\ ^4F_{5/2}$	3 645.57	0.0000	0.0000	1.745(3)	1.189(3)
	$3p^4(^3P)3d\ ^4P_{5/2}$	4 412.92	0.0000	0.0000	3.174(2)	2.793(2)
	$3p^4(^1D)4s\ ^2D_{5/2}$	4 609.55	0.2703	0.2662	6.361(7)	6.264(7)
	$3p^4(^3P)3d\ ^2F_{5/2}$	4 904.76	0.0229	0.0222	4.767(6)	4.608(6)
	$3p^4(^3P)3d\ ^2D_{5/2}$	5 141.81	0.1376	0.1293	2.601(7)	2.446(7)
	$3p^4(^1D)3d\ ^2F_{5/2}$	13 825.89	0.0007	0.0006	1.899(4)	1.673(4)
	$3p^4(^3P)3d\ ^4D_{7/2}$	2 616.81	0.0000	0.0000	2.749(4)	2.996(4)
	$3p^4(^3P)3d\ ^4F_{7/2}$	3 594.37	0.0000	0.0000	4.117(3)	3.942(3)
	$3p^4(^3P)3d\ ^2F_{7/2}$	4 682.29	0.0020	0.0015	6.187(5)	4.584(5)
	$3p^4(^1D)3d\ ^2G_{7/2}$	6 123.33	0.0044	0.0045	7.858(5)	8.022(5)
	$3p^4(^1D)3d\ ^2F_{7/2}$	14 233.19	0.0156	0.0137	5.141(5)	4.510(5)
	$3p^4(^3P)3d\ ^4F_{9/2}$	3 527.07	0.0000	0.0000	2.605(3)	1.775(3)
$3p^4(^1D)3d\ ^2G_{9/2}$	6 114.89	0.0965	0.0985	2.151(7)	2.196(7)	
Lifetime of upper state:				8.482(0)	8.662(0)	
$3p^4(^1D)4p\ ^2P_{3/2}$	$3s3p^6\ ^2S_{1/2}$	1 575.01	0.0306	0.0255	4.117(7)	3.429(7)
	$3p^4(^3P)3d\ ^4D_{1/2}$	2 532.45	0.0000	0.0000	4.039(-1)	6.537(0)
	$3p^4(^3P)4s\ ^4P_{1/2}$	2 730.57	0.0000	0.0000	6.060(3)	7.639(3)
	$3p^4(^3P)4s\ ^2P_{1/2}$	3 033.56	0.0276	0.0246	1.000(7)	8.922(6)
	$3p^4(^3P)3d\ ^2P_{1/2}$	3 634.89	0.0049	0.0041	1.230(6)	1.043(6)
	$3p^4(^3P)3d\ ^4P_{1/2}$	4 001.24	0.0003	0.0004	6.710(4)	7.211(4)
	$3p^4(^1S)4s\ ^2S_{1/2}$	20 380.57	0.0077	0.0024	6.181(4)	1.941(4)
	$3p^4(^3P)3d\ ^4D_{3/2}$	2 525.61	0.0000	0.0000	1.490(1)	1.127(0)
	$3p^4(^3P)4s\ ^4P_{3/2}$	2 692.65	0.0006	0.0006	5.626(5)	5.178(5)
	$3p^4(^3P)4s\ ^2P_{3/2}$	2 942.94	0.0693	0.0637	5.336(7)	4.900(7)
	$3p^4(^3P)3d\ ^4F_{3/2}$	3 466.19	0.0000	0.0000	2.788(0)	3.390(1)
	$3p^4(^3P)3d\ ^2P_{3/2}$	3 766.21	0.0201	0.0194	9.467(6)	9.140(6)
	$3p^4(^1D)4s\ ^2D_{3/2}$	4 237.32	0.0293	0.0285	1.086(7)	1.056(7)
	$3p^4(^3P)3d\ ^4P_{3/2}$	4 045.79	0.0001	0.0001	3.609(4)	4.593(4)
	$3p^4(^3P)3d\ ^2D_{3/2}$	4 598.91	0.0252	0.0211	7.928(6)	6.660(6)
	$3p^4(^3P)3d\ ^4D_{5/2}$	2 516.10	0.0000	0.0000	1.375(3)	1.080(3)
	$3p^4(^3P)4s\ ^4P_{5/2}$	2 632.77	0.0000	0.0000	5.468(3)	2.125(3)
	$3p^4(^3P)3d\ ^4F_{5/2}$	3 434.78	0.0000	0.0000	7.606(1)	2.795(2)
	$3p^4(^3P)3d\ ^4P_{5/2}$	4 107.76	0.0000	0.0000	1.833(4)	2.095(4)
	$3p^4(^1D)4s\ ^2D_{5/2}$	4 277.66	0.0944	0.1020	5.157(7)	5.575(7)
	$3p^4(^3P)3d\ ^2F_{5/2}$	4 530.68	0.0055	0.0056	2.672(6)	2.724(6)
	$3p^4(^3P)3d\ ^2D_{5/2}$	4 732.20	0.0561	0.0479	2.507(7)	2.141(7)
	$3p^4(^1D)3d\ ^2F_{5/2}$	11 215.56	0.0016	0.0013	1.229(5)	1.066(5)
	Lifetime of upper state:				4.668(0)	4.992(0)
$3p^4(^1D)4p\ ^2P_{1/2}$	$3s3p^6\ ^2S_{1/2}$	1 560.13	0.0153	0.0128	4.205(7)	3.496(7)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_v	A_l	A_v
Upper	Lower					
$3p^4(^1D)4p^2P_{1/2}$	$3p^4(^3P)3d^4D_{1/2}$	2 494.18	0.0000	0.0000	2.169(2)	6.439(-3)
	$3p^4(^3P)4s^4P_{1/2}$	2 686.13	0.0001	0.0001	1.014(5)	9.205(4)
	$3p^4(^3P)4s^2P_{1/2}$	2 978.81	0.0518	0.0501	3.890(7)	3.766(7)
	$3p^4(^3P)3d^2P_{1/2}$	3 556.57	0.0148	0.0121	7.800(6)	6.355(6)
	$3p^4(^3P)3d^4P_{1/2}$	3 906.54	0.0000	0.0000	1.630(4)	9.266(3)
	$3p^4(^1S)4s^2S_{1/2}$	18 140.83	0.0037	0.0009	7.526(4)	1.780(4)
	$3p^4(^3P)3d^4D_{3/2}$	2 487.54	0.0000	0.0000	4.233(1)	1.074(2)
	$3p^4(^3P)4s^4P_{3/2}$	2 649.41	0.0001	0.0001	1.356(5)	1.447(5)
	$3p^4(^3P)4s^2P_{3/2}$	2 891.39	0.0102	0.0098	1.625(7)	1.568(7)
	$3p^4(^3P)3d^4F_{3/2}$	3 394.90	0.0000	0.0000	8.209(2)	3.292(2)
	$3p^4(^3P)3d^2P_{3/2}$	3 682.17	0.0009	0.0009	9.040(5)	9.096(5)
	$3p^4(^1D)4s^2D_{3/2}$	4 131.27	0.1083	0.1075	8.459(7)	8.394(7)
	$3p^4(^3P)3d^4P_{3/2}$	3 948.97	0.0019	0.0017	1.612(6)	1.419(6)
	$3p^4(^3P)3d^2D_{3/2}$	4 474.21	0.0463	0.0371	3.086(7)	2.473(7)
	Lifetime of upper state:				4.478(0)	4.856(0)
$3p^4(^1D)4p^2D_{3/2}$	$3s3p^6^2S_{1/2}$	1 547.36	0.0005	0.0004	7.076(5)	5.570(5)
	$3p^4(^3P)3d^4D_{1/2}$	2 461.68	0.0000	0.0000	2.316(3)	7.478(2)
	$3p^4(^3P)4s^4P_{1/2}$	2 648.48	0.0000	0.0000	3.168(1)	2.223(2)
	$3p^4(^3P)4s^2P_{1/2}$	2 932.58	0.0016	0.0029	6.164(5)	1.118(6)
	$3p^4(^3P)3d^2P_{1/2}$	3 490.86	0.0222	0.0179	6.072(6)	4.888(6)
	$3p^4(^3P)3d^4P_{1/2}$	3 827.41	0.0002	0.0002	3.917(4)	3.574(4)
	$3p^4(^1S)4s^2S_{1/2}$	16 551.73	0.0002	0.0001	2.010(3)	6.700(2)
	$3p^4(^3P)3d^4D_{3/2}$	2 455.22	0.0000	0.0000	9.229(3)	9.125(3)
	$3p^4(^3P)4s^4P_{3/2}$	2 612.79	0.0000	0.0000	2.627(2)	8.263(1)
	$3p^4(^3P)4s^2P_{3/2}$	2 847.81	0.0004	0.0003	3.499(5)	2.376(5)
	$3p^4(^3P)3d^4F_{3/2}$	3 334.98	0.0000	0.0000	2.969(2)	1.681(2)
	$3p^4(^3P)3d^2P_{3/2}$	3 611.81	0.0025	0.0021	1.284(6)	1.084(6)
	$3p^4(^1D)4s^2D_{3/2}$	4 042.88	0.1056	0.0987	4.306(7)	4.025(7)
	$3p^4(^3P)3d^4P_{3/2}$	3 868.16	0.0014	0.0012	6.190(5)	5.203(5)
	$3p^4(^3P)3d^2D_{3/2}$	4 370.76	0.2027	0.1847	7.072(7)	6.447(7)
	$3p^4(^1D)3d^2D_{3/2}$	192 903.75	0.0015	0.0024	2.769(2)	4.234(2)
	$3p^4(^3P)3d^4D_{5/2}$	2 446.24	0.0000	0.0000	3.510(2)	5.800(2)
	$3p^4(^3P)4s^4P_{5/2}$	2 556.37	0.0000	0.0000	1.287(3)	1.782(3)
	$3p^4(^3P)3d^4F_{5/2}$	3 305.89	0.0000	0.0000	3.729(3)	4.415(3)
	$3p^4(^3P)3d^4P_{5/2}$	3 924.77	0.0000	0.0000	6.568(3)	5.989(3)
	$3p^4(^1D)4s^2D_{5/2}$	4 079.58	0.0122	0.0127	7.316(6)	7.642(6)
	$3p^4(^3P)3d^2F_{5/2}$	4 309.08	0.0118	0.0107	6.331(6)	5.750(6)
	$3p^4(^3P)3d^2D_{5/2}$	4 490.98	0.0234	0.0224	1.161(7)	1.113(7)
	$3p^4(^1D)3d^2F_{5/2}$	9 949.04	0.0483	0.0428	4.883(6)	4.328(6)
	$3p^4(^1D)3d^2D_{5/2}$	98 759.05	0.0000	0.0035	2.745(1)	3.541(3)
	Lifetime of upper state:				6.509(0)	7.041(0)
$3p^4(^1D)4p^2D_{5/2}$	$3p^4(^3P)3d^4D_{3/2}$	2 452.47	0.0000	0.0000	1.829(1)	5.959(1)
	$3p^4(^3P)4s^4P_{3/2}$	2 609.67	0.0000	0.0000	2.300(3)	2.421(0)
	$3p^4(^3P)4s^2P_{3/2}$	2 844.13	0.0002	0.0007	8.455(4)	3.808(5)
	$3p^4(^3P)3d^4F_{3/2}$	3 329.93	0.0000	0.0000	1.442(2)	1.061(2)
	$3p^4(^3P)3d^2P_{3/2}$	3 605.89	0.0140	0.0125	4.778(6)	4.269(6)
	$3p^4(^1D)4s^2D_{3/2}$	4 035.46	0.0197	0.0187	5.377(6)	5.116(6)
	$3p^4(^3P)3d^4P_{3/2}$	3 861.33	0.0014	0.0012	4.061(5)	3.657(5)
	$3p^4(^3P)3d^2D_{3/2}$	4 362.04	0.0260	0.0236	6.065(6)	5.520(6)
	$3p^4(^1D)3d^2D_{3/2}$	177 343.66	0.0002	0.0003	3.053(1)	4.803(1)
	$3p^4(^3P)3d^4D_{5/2}$	2 443.51	0.0000	0.0000	1.398(4)	1.454(4)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^1D)4p^2D_{5/2}$	$3p^4(^3P)4s^4P_{5/2}$	2553.40	0.0000	0.0000	1.149(4)	1.373(4)
	$3p^4(^3P)3d^4F_{5/2}$	3300.93	0.0000	0.0000	1.507(1)	3.299(1)
	$3p^4(^3P)3d^4P_{5/2}$	3917.77	0.0001	0.0001	5.712(4)	5.564(4)
	$3p^4(^1D)4s^2D_{5/2}$	4071.98	0.0851	0.0853	3.422(7)	3.429(7)
	$3p^4(^3P)3d^2F_{5/2}$	4300.65	0.0117	0.0118	4.199(6)	4.271(6)
	$3p^4(^3P)3d^2D_{5/2}$	4481.82	0.2446	0.2376	8.118(7)	7.887(7)
	$3p^4(^1D)3d^2F_{5/2}$	9904.23	0.0020	0.0015	1.330(5)	1.040(5)
	$3p^4(^1D)3d^2D_{5/2}$	94493.97	0.0025	0.0133	1.883(3)	9.919(3)
	$3p^4(^3P)3d^4D_{7/2}$	2434.36	0.0000	0.0000	9.909(3)	1.261(4)
	$3p^4(^3P)3d^4F_{7/2}$	3258.89	0.0000	0.0000	6.286(3)	7.364(3)
	$3p^4(^3P)3d^2F_{7/2}$	4128.64	0.0041	0.0035	2.118(6)	1.833(6)
	$3p^4(^1D)3d^2G_{7/2}$	5209.78	0.0000	0.0000	6.831(3)	3.011(3)
	$3p^4(^1D)3d^2F_{7/2}$	10111.50	0.0526	0.0466	4.575(6)	4.050(6)
	Lifetime of upper state:				6.981(0)	7.184(0)
$3p^4(^1S)4p^2P_{1/2}$	$3s3p^6^2S_{1/2}$	1196.00	0.0001	0.0000	4.610(5)	3.139(4)
	$3p^4(^3P)3d^4D_{1/2}$	1677.97	0.0000	0.0000	1.642(3)	1.682(3)
	$3p^4(^3P)4s^4P_{1/2}$	1762.68	0.0000	0.0000	3.470(4)	2.018(4)
	$3p^4(^3P)4s^2P_{1/2}$	1884.12	0.0013	0.0010	2.419(6)	1.881(6)
	$3p^4(^3P)3d^2P_{1/2}$	2099.13	0.0012	0.0011	1.818(6)	1.743(6)
	$3p^4(^3P)3d^4P_{1/2}$	2216.33	0.0000	0.0000	5.343(3)	8.935(3)
	$3p^4(^1S)4s^2S_{1/2}$	3994.78	0.3319	0.2672	1.387(8)	1.116(8)
	$3p^4(^1D)3d^2P_{1/2}$	5513.41	0.0000	0.0000	6.865(-1)	6.631(3)
	$3p^4(^1D)3d^2S_{1/2}$	12131.94	0.0149	0.0277	6.751(5)	1.256(6)
	$3p^4(^3P)3d^4D_{3/2}$	1674.97	0.0000	0.0000	8.795(2)	3.867(1)
	$3p^4(^3P)4s^4P_{3/2}$	1746.80	0.0000	0.0000	2.691(4)	2.420(4)
	$3p^4(^3P)4s^2P_{3/2}$	1848.77	0.0004	0.0003	1.538(6)	1.221(6)
	$3p^4(^3P)3d^4F_{3/2}$	2041.74	0.0000	0.0000	4.635(3)	1.103(4)
	$3p^4(^3P)3d^2P_{3/2}$	2142.28	0.0004	0.0004	1.215(6)	1.187(6)
	$3p^4(^1D)4s^2D_{3/2}$	2286.92	0.0000	0.0000	4.375(4)	3.091(4)
	$3p^4(^3P)3d^4P_{3/2}$	2229.94	0.0000	0.0000	7.345(4)	6.756(4)
	$3p^4(^3P)3d^2D_{3/2}$	2388.27	0.0078	0.0069	1.815(7)	1.623(7)
	$3p^4(^1D)3d^2D_{3/2}$	5125.76	0.0000	0.0002	2.545(3)	1.015(5)
	$3p^4(^1D)3d^2P_{3/2}$	5577.71	0.0010	0.0008	4.100(5)	3.312(5)
	$3p^4(^1S)3d^2D_{3/2}$	8061.22	0.0712	0.0467	1.460(7)	9.586(6)
	Lifetime of upper state:				5.551(0)	6.880(0)
$3p^4(^1S)4p^2P_{3/2}$	$3s3p^6^2S_{1/2}$	1201.16	0.0002	0.0000	5.354(5)	1.140(4)
	$3p^4(^3P)3d^4D_{1/2}$	1688.14	0.0000	0.0000	4.455(2)	4.308(2)
	$3p^4(^3P)4s^4P_{1/2}$	1773.90	0.0000	0.0000	7.338(2)	6.021(1)
	$3p^4(^3P)4s^2P_{1/2}$	1896.95	0.0009	0.0005	7.870(5)	5.107(5)
	$3p^4(^3P)3d^2P_{1/2}$	2115.08	0.0007	0.0006	5.054(5)	4.617(5)
	$3p^4(^3P)3d^4P_{1/2}$	2234.11	0.0000	0.0000	6.949(3)	4.211(3)
	$3p^4(^1S)4s^2S_{1/2}$	4052.91	0.6513	0.5441	1.321(8)	1.104(8)
	$3p^4(^1D)3d^2P_{1/2}$	5624.76	0.0006	0.0004	5.959(4)	3.880(4)
	$3p^4(^1D)3d^2S_{1/2}$	12684.50	0.0287	0.0576	5.937(5)	1.194(6)
	$3p^4(^3P)3d^4D_{3/2}$	1685.10	0.0000	0.0000	8.395(2)	1.301(3)
	$3p^4(^3P)4s^4P_{3/2}$	1757.82	0.0000	0.0000	4.417(4)	3.485(4)
	$3p^4(^3P)4s^2P_{3/2}$	1861.12	0.0014	0.0010	2.740(6)	1.925(6)
	$3p^4(^3P)3d^4F_{3/2}$	2056.82	0.0000	0.0000	4.907(2)	9.993(2)
	$3p^4(^3P)3d^2P_{3/2}$	2158.88	0.0016	0.0015	2.260(6)	2.209(6)
	$3p^4(^1D)4s^2D_{3/2}$	2305.85	0.0000	0.0000	3.849(3)	9.200(3)
	$3p^4(^3P)3d^4P_{3/2}$	2247.94	0.0000	0.0000	3.702(4)	4.215(4)

Table 5. (continued)

States		$\lambda_{\text{calc}} (\text{\AA})$	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^1S)4p^2P_{3/2}$	$3p^4(^3P)3d^2D_{3/2}$	2 408.92	0.0019	0.0017	2.166(6)	1.968(6)
	$3p^4(^1D)3d^2D_{3/2}$	5 221.87	0.0000	0.0001	1.438(3)	2.110(4)
	$3p^4(^1D)3d^2P_{3/2}$	5 691.63	0.0000	0.0000	3.929(3)	1.318(-1)
	$3p^4(^1S)3d^2D_{3/2}$	8 301.50	0.0140	0.0098	1.352(6)	9.481(5)
	$3p^4(^3P)3d^4D_{5/2}$	1 680.86	0.0000	0.0000	5.484(0)	8.817(2)
	$3p^4(^3P)4s^4P_{5/2}$	1 732.12	0.0000	0.0000	3.715(1)	2.502(1)
	$3p^4(^3P)3d^4F_{5/2}$	2 045.72	0.0000	0.0000	2.209(3)	4.855(3)
	$3p^4(^3P)3d^4P_{5/2}$	2 266.94	0.0000	0.0000	3.247(4)	2.253(4)
	$3p^4(^1D)4s^2D_{5/2}$	2 317.75	0.0003	0.0002	5.997(5)	3.813(5)
	$3p^4(^3P)3d^2F_{5/2}$	2 390.08	0.0002	0.0002	3.292(5)	3.011(5)
	$3p^4(^3P)3d^2D_{5/2}$	2 445.01	0.0101	0.0092	1.691(7)	1.540(7)
	$3p^4(^1D)3d^2F_{5/2}$	3 486.35	0.0000	0.0000	8.681(3)	6.395(3)
	$3p^4(^1D)3d^2D_{5/2}$	5 090.51	0.0003	0.0000	1.010(5)	2.398(3)
	$3p^4(^1S)3d^2D_{5/2}$	8 073.77	0.0856	0.0597	1.313(7)	9.153(6)
	Lifetime of upper state:				5.735(0)	6.893(0)
$3s3p^6^2S_{1/2}$	$3s^23p^5^2P_{1/2}$	932.05	0.0113	0.0112	8.671(7)	8.595(7)
	$3s^23p^5^2P_{3/2}$	919.78	0.0114	0.0110	1.797(8)	1.734(8)
	Lifetime of upper state:				3.754(0)	3.856(0)
$3p^4(^3P)4s^4P_{5/2}$	$3s^23p^5^2P_{3/2}$	744.93	0.0002	0.0002	1.991(6)	1.513(6)
	Lifetime of upper state:				5.023(2)	6.609(2)
$3p^4(^3P)4s^4P_{3/2}$	$3s^23p^5^2P_{1/2}$	748.20	0.0005	0.0004	3.212(6)	2.609(6)
	$3s^23p^5^2P_{3/2}$	740.27	0.0031	0.0026	3.807(7)	3.122(7)
	Lifetime of upper state:				2.422(1)	2.956(1)
$3p^4(^3P)4s^4P_{1/2}$	$3s^23p^5^2P_{1/2}$	745.32	0.0009	0.0007	1.043(7)	8.295(6)
	$3s^23p^5^2P_{3/2}$	737.45	0.0000	0.0000	1.343(5)	1.243(5)
	Lifetime of upper state:				9.466(1)	1.188(2)
$3p^4(^3P)4s^2P_{3/2}$	$3s^23p^5^2P_{1/2}$	730.93	0.0610	0.0513	3.811(8)	3.202(8)
	$3s^23p^5^2P_{3/2}$	723.36	0.1863	0.1590	2.375(9)	2.027(9)
	Lifetime of upper state:				3.628(-1)	4.260(-1)
$3p^4(^3P)4s^2P_{1/2}$	$3s^23p^5^2P_{1/2}$	725.55	0.1398	0.1177	1.771(9)	1.492(9)
	$3s^23p^5^2P_{3/2}$	718.09	0.0384	0.0328	9.924(8)	8.482(8)
	Lifetime of upper state:				3.619(-1)	4.273(-1)
$3p^4(^1D)4s^2D_{3/2}$	$3s^23p^5^2P_{1/2}$	679.40	0.0363	0.0320	2.620(8)	2.309(8)
	$3s^23p^5^2P_{3/2}$	672.86	0.0004	0.0002	5.478(6)	3.635(6)
	Lifetime of upper state:				3.738(0)	4.264(0)
$3p^4(^1D)4s^2D_{5/2}$	$3s^23p^5^2P_{3/2}$	671.85	0.0119	0.0099	1.169(8)	9.758(7)
	Lifetime of upper state:				8.551(0)	1.025(1)
$3p^4(^1S)4s^2S_{1/2}$	$3s^23p^5^2P_{1/2}$	602.86	0.0697	0.0700	1.279(9)	1.284(9)
	$3p^4(^3P)4p^4P_{1/2}$	8 618.39	0.0000	0.0001	2.933(3)	4.850(3)
	$3p^4(^3P)4p^4D_{1/2}$	11 258.44	0.0000	0.0000	2.442(3)	1.629(3)
	$3p^4(^3P)4p^2P_{1/2}$	13 150.74	0.0021	0.0027	8.208(4)	1.041(5)
	$3p^4(^3P)4p^2S_{1/2}$	16 076.46	0.0001	0.0002	3.730(3)	4.051(3)
	$3s^23p^5^2P_{3/2}$	597.70	0.0703	0.0694	2.624(9)	2.590(9)
	$3p^4(^3P)4p^4P_{3/2}$	8 361.05	0.0000	0.0001	7.983(3)	1.295(4)
	$3p^4(^3P)4p^4D_{3/2}$	10 937.72	0.0000	0.0000	1.227(3)	5.702(2)
	$3p^4(^3P)4p^2D_{3/2}$	12 631.57	0.0003	0.0003	2.319(4)	2.264(4)
	$3p^4(^3P)4p^2P_{3/2}$	14 143.13	0.0018	0.0014	1.197(5)	9.668(4)
	$3p^4(^3P)4p^4S_{3/2}$	15 972.02	0.0000	0.0001	1.241(3)	2.732(3)
	Lifetime of upper state:				2.562(-1)	2.581(-1)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^3P)3d^4D_{5/2}$	$3s^23p^5^2P_{3/2}$	754.82	0.0000	0.0000	1.138(5)	2.261(5)
		Lifetime of upper state:			8.791(3)	4.422(3)
$3p^4(^3P)3d^4D_{3/2}$	$3s^23p^5^2P_{1/2}$	762.20	0.0000	0.0000	7.596(4)	1.203(5)
	$3s^23p^5^2P_{3/2}$	753.97	0.0000	0.0000	2.087(3)	3.718(3)
		Lifetime of upper state:			1.281(4)	8.063(3)
$3p^4(^3P)3d^4D_{1/2}$	$3s^23p^5^2P_{1/2}$	761.58	0.0000	0.0000	6.239(3)	8.393(2)
	$3s^23p^5^2P_{3/2}$	753.37	0.0000	0.0000	2.134(3)	6.628(2)
		Lifetime of upper state:			1.194(5)	6.658(5)
$3p^4(^3P)3d^4F_{5/2}$	$3s^23p^5^2P_{3/2}$	698.78	0.0001	0.0001	9.124(5)	1.149(6)
		Lifetime of upper state:			1.096(3)	8.703(2)
$3p^4(^3P)3d^4F_{3/2}$	$3s^23p^5^2P_{1/2}$	704.52	0.0002	0.0003	1.374(6)	1.743(6)
	$3s^23p^5^2P_{3/2}$	697.49	0.0000	0.0000	2.888(5)	3.672(5)
		Lifetime of upper state:			6.014(2)	4.739(2)
$3p^4(^3P)3d^2P_{1/2}$	$3s^23p^5^2P_{1/2}$	697.94	0.0045	0.0068	6.149(7)	9.266(7)
	$3s^23p^5^2P_{3/2}$	691.04	0.0009	0.0015	2.660(7)	4.075(7)
		Lifetime of upper state:			1.135(1)	7.496(0)
$3p^4(^3P)3d^2P_{3/2}$	$3s^23p^5^2P_{1/2}$	693.30	0.0004	0.0008	2.686(6)	5.461(6)
	$3s^23p^5^2P_{3/2}$	686.49	0.0016	0.0025	2.216(7)	3.554(7)
		Lifetime of upper state:			4.026(1)	2.439(1)
$3p^4(^3P)3d^4P_{1/2}$	$3s^23p^5^2P_{1/2}$	685.89	0.0000	0.0000	1.039(5)	1.335(5)
	$3s^23p^5^2P_{3/2}$	679.22	0.0001	0.0000	1.321(6)	1.263(6)
		Lifetime of upper state:			7.017(2)	7.160(2)
$3p^4(^3P)3d^4P_{3/2}$	$3s^23p^5^2P_{1/2}$	684.60	0.0008	0.0007	5.572(6)	5.156(6)
	$3s^23p^5^2P_{3/2}$	677.95	0.0002	0.0002	2.699(6)	2.454(6)
		Lifetime of upper state:			1.209(2)	1.314(2)
$3p^4(^3P)3d^4P_{5/2}$	$3s^23p^5^2P_{3/2}$	676.24	0.0004	0.0004	4.420(6)	4.248(6)
		Lifetime of upper state:			2.262(2)	2.354(2)
$3p^4(^3P)3d^2F_{5/2}$	$3s^23p^5^2P_{3/2}$	666.01	0.0073	0.0065	7.295(7)	6.474(7)
		Lifetime of upper state:			1.371(1)	1.545(1)
$3p^4(^3P)3d^2D_{3/2}$	$3s^23p^5^2P_{1/2}$	670.95	0.1625	0.1457	1.203(9)	1.080(9)
	$3s^23p^5^2P_{3/2}$	664.56	0.0149	0.0137	2.243(8)	2.076(8)
		Lifetime of upper state:			7.005(-1)	7.767(-1)
$3p^4(^3P)3d^2D_{5/2}$	$3s^23p^5^2P_{3/2}$	661.87	0.1610	0.1467	1.635(9)	1.489(9)
		Lifetime of upper state:			6.118(-1)	6.718(-1)
$3p^4(^1D)3d^2F_{5/2}$	$3s^23p^5^2P_{3/2}$	612.37	0.0007	0.0007	7.911(6)	8.042(6)
	$3p^4(^3P)4p^4P_{3/2}$	12 577.58	0.0000	0.0000	4.055(2)	6.577(2)
	$3p^4(^3P)4p^4D_{3/2}$	19 481.33	0.0005	0.0006	6.189(3)	7.465(3)
	$3p^4(^3P)4p^4D_{5/2}$	25 594.26	0.0058	0.0068	3.915(4)	4.629(4)
	$3p^4(^3P)4p^4P_{3/2}$	32 668.83	0.0005	0.0003	2.048(3)	1.139(3)
	$3p^4(^3P)4p^4S_{3/2}$	44 416.77	0.0000	0.0000	1.437(-1)	6.676(-4)
	$3p^4(^3P)4p^4P_{5/2}$	12 108.53	0.0000	0.0000	2.701(0)	1.045(1)
	$3p^4(^3P)4p^4D_{5/2}$	17 769.33	0.0002	0.0003	4.282(3)	5.737(3)
	$3p^4(^3P)4p^4D_{5/2}$	21 879.04	0.0006	0.0007	7.827(3)	1.034(4)
	$3p^4(^3P)4p^4D_{7/2}$	16 482.24	0.0000	0.0000	2.670(1)	4.021(1)
		Lifetime of upper state:			1.255(2)	1.232(2)
$3p^4(^1D)3d^2F_{7/2}$	$3p^4(^3P)4p^4P_{5/2}$	11 812.49	0.0000	0.0000	1.293(2)	2.975(2)
	$3p^4(^3P)4p^4D_{5/2}$	17 138.99	0.0016	0.0019	2.708(4)	3.194(4)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_v	A_l	A_v
Upper	Lower					
$3p^4(^1D)3d^2F_{7/2}$	$3p^4(^3P)4p^2D_{5/2}$	20 931.18	0.0063	0.0074	7.201(4)	8.395(4)
	$3p^4(^3P)4p^4D_{7/2}$	15 937.95	0.0000	0.0000	6.429(2)	9.455(2)
	Lifetime of upper state:				1.001(4)	8.537(3)
$3p^4(^1D)3d^2D_{5/2}$	$3s^23p^5^2P_{3/2}$	580.26	0.5199	0.4801	6.866(9)	6.340(9)
	$3p^4(^3P)4p^4P_{3/2}$	5 886.11	0.0013	0.0019	1.623(5)	2.472(5)
	$3p^4(^3P)4p^4D_{3/2}$	7 056.27	0.0006	0.0008	4.985(4)	7.086(4)
	$3p^4(^3P)4p^2D_{3/2}$	7 724.52	0.0094	0.0151	6.999(5)	1.124(6)
	$3p^4(^3P)4p^2P_{3/2}$	8 264.83	0.1483	0.2519	9.652(6)	1.639(7)
	$3p^4(^3P)4p^4S_{3/2}$	8 857.35	0.0000	0.0000	5.151(-2)	3.478(2)
	$3p^4(^1D)4p^2P_{3/2}$	816 591.56	0.0014	0.5681	9.562(0)	3.786(3)
	$3p^4(^3P)4p^4P_{5/2}$	5 781.23	0.0004	0.0005	7.540(4)	1.008(5)
	$3p^4(^3P)4p^4D_{5/2}$	6 818.33	0.0105	0.0169	1.503(6)	2.427(6)
	$3p^4(^3P)4p^2D_{5/2}$	7 348.06	0.0484	0.0803	5.972(6)	9.917(6)
	$3p^4(^1D)4p^2F_{5/2}$	51 674.66	0.0000	0.0000	3.744(1)	1.864(1)
	$3p^4(^3P)4p^4D_{7/2}$	6 619.96	0.0000	0.0000	1.179(3)	1.981(3)
	$3p^4(^1D)4p^2F_{7/2}$	55 382.83	0.0003	0.0032	7.336(2)	9.280(3)
	Lifetime of upper state:				1.453(-1)	1.570(-1)
$3p^4(^1D)3d^2D_{3/2}$	$3s^23p^5^2P_{1/2}$	583.44	0.4773	0.4383	4.676(9)	4.294(9)
	$3p^4(^3P)4p^4P_{1/2}$	5 838.94	0.0016	0.0022	1.599(5)	2.123(5)
	$3p^4(^3P)4p^4D_{1/2}$	6 941.78	0.0033	0.0046	2.309(5)	3.191(5)
	$3p^4(^3P)4p^2P_{1/2}$	7 617.64	0.1451	0.2189	8.338(6)	1.258(7)
	$3p^4(^3P)4p^2S_{1/2}$	8 515.30	0.0068	0.0127	3.136(5)	5.854(5)
	$3p^4(^1D)4p^2P_{1/2}$	9416 606.00	0.0001	5.7483	4.668(-3)	2.161(2)
	$3s^23p^5^2P_{3/2}$	578.60	0.0934	0.0867	1.862(9)	1.728(9)
	$3p^4(^3P)4p^4P_{3/2}$	5 719.74	0.0001	0.0002	1.989(4)	3.108(4)
	$3p^4(^3P)4p^4D_{3/2}$	6 818.50	0.0045	0.0071	6.465(5)	1.014(6)
	$3p^4(^3P)4p^2D_{3/2}$	7 440.49	0.0672	0.1101	8.089(6)	1.326(7)
	$3p^4(^3P)4p^2P_{3/2}$	7 940.52	0.0017	0.0023	1.814(5)	2.467(5)
	$3p^4(^3P)4p^4S_{3/2}$	8 485.91	0.0000	0.0000	2.698(2)	1.624(2)
	$3p^4(^1D)4p^2P_{3/2}$	162 171.20	0.0009	0.0237	2.285(2)	6.010(3)
	$3p^4(^3P)4p^4P_{5/2}$	5 620.65	0.0000	0.0000	1.174(4)	1.538(4)
	$3p^4(^3P)4p^4D_{5/2}$	6 596.07	0.0008	0.0011	1.932(5)	2.598(5)
	$3p^4(^3P)4p^2D_{5/2}$	7 090.58	0.0042	0.0058	8.400(5)	1.162(6)
	$3p^4(^1D)4p^2F_{5/2}$	41 163.16	0.0004	0.0030	2.428(3)	1.778(4)
	Lifetime of upper state:				1.525(-1)	1.652(-1)
$3p^4(^1D)3d^2P_{1/2}$	$3s^23p^5^2P_{1/2}$	578.81	0.2893	0.2809	5.759(9)	5.592(9)
	$3p^4(^3P)4p^4P_{1/2}$	5 405.96	0.0022	0.0025	5.092(5)	5.704(5)
	$3p^4(^3P)4p^4D_{1/2}$	6 338.26	0.0011	0.0012	1.808(5)	1.926(5)
	$3p^4(^3P)4p^2P_{1/2}$	6 896.98	0.0773	0.0906	1.083(7)	1.269(7)
	$3p^4(^3P)4p^2S_{1/2}$	7 624.72	0.0778	0.0858	8.922(6)	9.838(6)
	$3p^4(^1D)4p^2P_{1/2}$	72 332.52	0.0087	0.0558	1.105(4)	7.111(4)
	$3s^23p^5^2P_{3/2}$	574.05	0.0770	0.0743	3.118(9)	3.008(9)
	$3p^4(^3P)4p^4P_{3/2}$	5 303.57	0.0000	0.0000	5.972(3)	4.294(3)
	$3p^4(^3P)4p^4D_{3/2}$	6 235.33	0.0005	0.0003	1.781(5)	1.076(5)
	$3p^4(^3P)4p^2D_{3/2}$	6 751.45	0.0078	0.0049	2.296(6)	1.428(6)
	$3p^4(^3P)4p^2P_{3/2}$	7 160.49	0.0017	0.0033	4.396(5)	8.508(5)
	$3p^4(^3P)4p^4S_{3/2}$	7 601.15	0.0000	0.0000	5.648(3)	8.456(3)
	$3p^4(^1D)4p^2P_{3/2}$	50 294.36	0.0027	0.0141	1.404(4)	7.421(4)
	$3p^4(^1D)4p^2D_{3/2}$	117 196.38	0.0009	0.0239	8.578(2)	2.323(4)
	Lifetime of upper state:				1.124(-1)	1.159(-1)
$3p^4(^1D)3d^2P_{3/2}$	$3s^23p^5^2P_{1/2}$	578.11	0.2060	0.1961	2.055(9)	1.957(9)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_u	A_l	A_u
Upper	Lower					
$3p^4(^1D)3d^2P_{3/2}$	$3p^4(^3P)4p^4P_{1/2}$	5 345.60	0.0012	0.0013	1.403(5)	1.486(5)
	$3p^4(^3P)4p^4D_{1/2}$	6 255.36	0.0000	0.0000	2.164(3)	3.138(3)
	$3p^4(^3P)4p^2P_{1/2}$	6 799.03	0.0039	0.0030	2.826(5)	2.197(5)
	$3p^4(^3P)4p^2S_{1/2}$	7 505.20	0.2687	0.3057	1.590(7)	1.808(7)
	$3p^4(^1D)4p^2P_{1/2}$	62 838.89	0.0070	0.0235	5.906(3)	1.988(4)
	$3s^23p^5^2P_{3/2}$	573.36	0.3422	0.3307	6.942(9)	6.710(9)
	$3p^4(^3P)4p^4P_{3/2}$	5 245.46	0.0002	0.0003	4.515(4)	6.345(4)
	$3p^4(^3P)4p^4D_{3/2}$	6 155.16	0.0001	0.0001	1.065(4)	2.078(4)
	$3p^4(^3P)4p^2D_{3/2}$	6 657.46	0.0008	0.0020	1.172(5)	3.053(5)
	$3p^4(^3P)4p^2P_{3/2}$	7 054.97	0.0277	0.0361	3.711(6)	4.829(6)
	$3p^4(^3P)4p^4S_{3/2}$	7 482.36	0.0001	0.0001	9.256(3)	1.002(4)
	$3p^4(^1D)4p^2P_{3/2}$	45 508.72	0.0158	0.0400	5.093(4)	1.286(5)
	$3p^4(^1D)4p^2D_{3/2}$	94 130.46	0.0000	0.0000	3.094(1)	1.329(1)
	$3p^4(^3P)4p^4P_{5/2}$	5 162.07	0.0001	0.0001	1.998(4)	2.219(4)
	$3p^4(^3P)4p^4D_{5/2}$	5 973.33	0.0008	0.0003	2.179(5)	8.233(4)
	$3p^4(^3P)4p^2D_{5/2}$	6 375.93	0.0037	0.0013	9.026(5)	3.146(5)
	$3p^4(^1D)4p^2F_{5/2}$	24 938.36	0.0000	0.0000	5.919(1)	7.469(2)
	$3p^4(^1D)4p^2D_{5/2}$	98 362.05	0.0007	0.0075	7.106(2)	7.757(3)
	Lifetime of upper state:				1.109(-1)	1.151(-1)
$3p^4(^1S)3d^2D_{5/2}$	$3s^23p^5^2P_{3/2}$	556.82	0.0508	0.0545	7.290(8)	7.812(8)
	$3p^4(^3P)4p^4P_{3/2}$	4 124.04	0.0006	0.0007	1.529(5)	1.733(5)
	$3p^4(^3P)4p^4D_{3/2}$	4 666.26	0.0008	0.0010	1.702(5)	1.987(5)
	$3p^4(^3P)4p^2D_{3/2}$	4 949.41	0.0060	0.0069	1.090(6)	1.249(6)
	$3p^4(^3P)4p^2P_{3/2}$	5 165.80	0.0519	0.0686	8.645(6)	1.142(7)
	$3p^4(^3P)4p^4S_{3/2}$	5 391.22	0.0000	0.0001	7.280(3)	9.499(3)
	$3p^4(^1D)4p^2P_{3/2}$	13 548.30	0.0005	0.0061	1.195(4)	1.481(5)
	$3p^4(^1D)4p^2D_{3/2}$	16 010.32	0.0007	0.0013	1.295(4)	2.195(4)
	$3p^4(^3P)4p^4P_{5/2}$	4 072.32	0.0000	0.0000	4.554(3)	9.321(3)
	$3p^4(^3P)4p^4D_{5/2}$	4 561.00	0.0029	0.0042	9.224(5)	1.346(6)
	$3p^4(^3P)4p^2D_{5/2}$	4 792.10	0.0098	0.0155	2.853(6)	4.499(6)
	$3p^4(^1D)4p^2F_{5/2}$	10 876.98	0.0001	0.0000	3.318(3)	2.329(3)
	$3p^4(^1D)4p^2D_{5/2}$	16 127.76	0.0048	0.0036	1.221(5)	9.361(4)
	$3p^4(^3P)4p^4D_{7/2}$	4 471.38	0.0000	0.0000	1.301(3)	6.595(2)
	$3p^4(^1D)4p^2F_{7/2}$	11 032.20	0.0008	0.0002	6.042(4)	1.745(4)
	Lifetime of upper state:				1.346(0)	1.249(0)
$3p^4(^1S)3d^2D_{3/2}$	$3s^23p^5^2P_{1/2}$	560.22	0.0939	0.0966	9.978(8)	1.026(9)
	$3p^4(^3P)4p^4P_{1/2}$	4 127.00	0.0007	0.0008	1.368(5)	1.610(5)
	$3p^4(^3P)4p^4D_{1/2}$	4 649.05	0.0037	0.0046	5.702(5)	7.071(5)
	$3p^4(^3P)4p^2P_{1/2}$	4 942.80	0.0743	0.0983	1.014(7)	1.342(7)
	$3p^4(^3P)4p^2S_{1/2}$	5 305.67	0.0269	0.0332	3.189(6)	3.931(6)
	$3p^4(^1D)4p^2P_{1/2}$	14 055.29	0.0042	0.0154	7.126(4)	2.606(5)
	$3s^23p^5^2P_{3/2}$	555.77	0.0009	0.0011	1.918(7)	2.407(7)
	$3p^4(^3P)4p^4P_{3/2}$	4 067.09	0.0001	0.0001	4.751(4)	5.366(4)
	$3p^4(^3P)4p^4D_{3/2}$	4 593.43	0.0024	0.0034	7.686(5)	1.068(6)
	$3p^4(^3P)4p^2D_{3/2}$	4 867.55	0.0229	0.0345	6.440(6)	9.698(6)
	$3p^4(^3P)4p^2P_{3/2}$	5 076.69	0.0004	0.0003	9.070(4)	7.442(4)
	$3p^4(^3P)4p^4S_{3/2}$	5 294.24	0.0000	0.0000	2.705(3)	3.488(3)
	$3p^4(^1D)4p^2P_{3/2}$	12 952.07	0.0000	0.0003	3.313(2)	1.028(4)
	$3p^4(^1D)4p^2D_{3/2}$	15 184.31	0.0037	0.0033	1.068(5)	9.677(4)
	$3p^4(^3P)4p^4P_{5/2}$	4 016.74	0.0000	0.0000	1.988(1)	2.110(1)
	$3p^4(^3P)4p^4D_{5/2}$	4 491.40	0.0003	0.0004	1.215(5)	1.951(5)
	$3p^4(^3P)4p^2D_{5/2}$	4 715.32	0.0007	0.0013	3.116(5)	5.882(5)

Table 5. (continued)

States		λ_{calc} (Å)	f_l	f_v	A_l	A_v
Upper	Lower					
$3p^4(^1S)3d^2D_{3/2}$	$3p^4(^1D)4p^2F_{5/2}$	10 489.33	0.0007	0.0003	6.175(4)	2.590(4)
	$3p^4(^1D)4p^2D_{5/2}$	15 289.91	0.0006	0.0008	2.458(4)	3.235(4)
		Lifetime of upper state:			9.624(-1)	9.256(-1)
$3p^4(^1D)3d^2S_{1/2}$	$3s^23p^5^2P_{1/2}$	547.46	0.1334	0.1431	2.967(9)	3.183(9)
	$3p^4(^3P)4p^4P_{1/2}$	3 521.97	0.0002	0.0004	1.022(5)	2.281(5)
	$3p^4(^3P)4p^4D_{1/2}$	3 895.26	0.0003	0.0004	1.197(5)	1.827(5)
	$3p^4(^3P)4p^2P_{1/2}$	4 099.35	0.0171	0.0334	6.779(6)	1.325(7)
	$3p^4(^3P)4p^2S_{1/2}$	4 345.90	0.0027	0.0049	9.394(5)	1.720(6)
	$3p^4(^1D)4p^2P_{1/2}$	8 867.33	0.0697	0.1634	5.911(6)	1.385(7)
	$3s^23p^5^2P_{3/2}$	543.20	0.1345	0.1419	6.078(9)	6.412(9)
	$3p^4(^3P)4p^4P_{3/2}$	3 478.22	0.0080	0.0099	8.779(6)	1.089(7)
	$3p^4(^3P)4p^4D_{3/2}$	3 856.14	0.0004	0.0005	3.534(5)	4.285(5)
	$3p^4(^3P)4p^2D_{3/2}$	4 047.49	0.0021	0.0042	1.680(6)	3.383(6)
	$3p^4(^3P)4p^2P_{3/2}$	4 191.02	0.0133	0.0258	1.009(7)	1.954(7)
	$3p^4(^3P)4p^4S_{3/2}$	4 338.23	0.0066	0.0081	4.657(6)	5.714(6)
	$3p^4(^1D)4p^2P_{3/2}$	8 415.28	0.0640	0.1496	1.205(7)	2.818(7)
	$3p^4(^1D)4p^2D_{3/2}$	9 303.96	0.0008	0.0020	1.191(5)	3.060(5)
		Lifetime of upper state:			1.099(-1)	1.032(-1)

ⁱ $a(b)$ implies $a \times 10^b$.

to errors in the calculated transition integrals. The level of agreement between length and velocity forms gives some measure of the accuracy of the calculations. For transitions which would be allowed in *LS* coupling, ($\Delta S = 0$; $\Delta L = 0, 1$ except for $L = 0 \rightarrow L' = 0$), length and velocity forms should agree. For intercombination lines, a correction to the velocity operator is necessary for such agreement (Drake 1972). That correction has not been included in the present calculations, so only the length form is 'correct' for these transitions. Most intercombination lines are weak, compared with allowed lines. For a few levels, there is quite strong mixing between quartets and doublets. In such cases, the intercombination lines are much stronger than usual, but the contribution from the velocity-operator correction is a small contribution to the total, so that length and the uncorrected velocity forms should still be in good agreement. An example of this is the $4p^4D_{5/2}^0-4s^2P_{3/2}$ transition at 5145 Å. The unusually large f -value is due to the strong interaction between $4D_{5/2}^0$ and $2D_{5/2}^0$. The length and velocity values are in excellent agreement.

The mean lifetime of a level is the reciprocal of the sum of all the probabilities of emission transitions from that level. The weak intercombination lines contribute a negligible amount. The lifetimes are determined almost entirely from the allowed and the strong intercombination transitions. For these, length and velocity forms should, as mentioned, be in good agreement. In the present work, this is largely the case. The length and velocity forms of the lifetimes mostly agree to within 5%. This is particularly true for the $4p$ quartet levels, since the radial functions were optimized so as to emphasize these levels. Many of the $4p$ doublet levels also agree to this accuracy. Only for the $3p^4(^1S)4p^2P$ levels, length and velocity lifetimes differ by more than about 10%. These lifetimes are determined by the single transition $3p^4(^1S)4p^2P^0-3p^4(^1S)4s^2S$. As we remarked earlier, these highest levels are probably less accurately described by their CI wavefunctions than are the lower lying levels.

3.3. Comparison with other work

Recent experimental work has been thoroughly reviewed by Vujnović and Wiese (1992). Their critical analysis of existing data enabled them to recommend lifetimes for the 4p and 4d levels, mostly to an accuracy of 10% and in some cases to an accuracy of 1%, as well as the relevant transition probabilities with an accuracy of about 10% or better.

Table 6. Comparison of calculated and experimental lifetimes (in ns) of 4p levels. References: A, Schmoranzner *et al* (1986), Marger and Schmoranzner (1990), the errors shown are one standard deviation; B, Ward *et al* (1985), the errors shown are one standard deviation; C, Schade *et al* (1989); D, Garcia and Campos (1985); E, this work; F, Luyken (1972), only length values are given explicitly in this paper. The velocity values shown here are obtained by summing over transition probabilities for individual lines reported by Luyken. However, we note that this summation is less complete than the one involved in the reported length values.

		Experiment†				Theory			
						E		F	
						<i>l</i>	<i>v</i>	<i>l</i>	<i>v</i>
3p ⁴ (³ P)4p	⁴ D _{7/2}	6.92(03)	6.79(09)	7.0(5)		6.67	7.07	5.57	6.14
	⁴ D _{5/2}	7.54(04)	7.30(09)	7.4(4)		7.22	7.55	6.11	7.65
	⁴ D _{3/2}			7.1(5)		6.90	7.25	5.78	7.48
	⁴ D _{1/2}			7.1(5)	8.0(3)	6.79	7.13	5.65	7.36
	⁴ P _{3/2}	7.36(03)		7.6(3)	8.0(5)	7.17	7.21	5.83	7.72
	⁴ P _{3/2}			7.7(4)	8.1(6)	7.23	7.26	5.88	7.77
	⁴ P _{1/2}			7.7(4)	8.1(5)	7.24	7.26	5.89	7.79
	⁴ S _{3/2}				7.5(5)	5.95	6.20	4.74	6.88
	² D _{5/2}	9.52(03)	9.57(11)		9.0(6)	9.58	9.94	8.45	9.22
	² D _{3/2}				8.5(5)	9.86	10.15	8.72	9.54
	² P _{3/2}				7.9(3)	9.05	9.36	8.04	9.73
	² P _{1/2}				8.0(6)	9.00	9.29	7.80	9.49
	² S _{1/2}				8.6(6)	8.50	9.39	7.50	8.63
	² F _{7/2}	8.41(03)			8.5(7)	8.48	8.66	7.36	8.13
3p ⁴ (¹ D)4p	² F _{5/2}	8.52(04)			8.9(3)	8.16	8.62	7.57	8.19
	² D _{5/2}				8.0(5)	6.98	7.18	5.80	7.91
	² D _{3/2}					6.51	7.04	5.70	7.97
	² P _{3/2}				5.4(2)	4.67	4.99	3.33	8.76
	² P _{1/2}				5.5(4)	4.48	4.86	3.26	7.51

† Experimental errors (in decimal places) given in parentheses.

In table 6, we compare our calculated lifetimes of the 4p levels with the corresponding calculations of Luyken (1972) and with the most reliable experimental work (see Vujnović and Wiese 1992). As mentioned, our length and velocity forms mostly agree to within 5%. There is excellent agreement between our calculated values and the experimental results obtained using the cascade-free beam-dye-laser method by Ward *et al* (1985), Schmoranzner *et al* (1986) and Marger and Schmoranzner (1990). These authors have so far considered only a few levels. Schade *et al* (1989) used selective pulsed laser excitation and time resolved observation of the re-emitted fluorescence to determine the lifetimes of the 4p ⁴P and ⁴D levels. In the former case, their lifetimes are consistently longer than our calculated values, or the $J = \frac{5}{2}$ value of Schmoranzner *et al* (1986), but there is good agreement for all ⁴D levels. The most complete set of experimental lifetimes is provided by Garcia and Campos (1985), who used the delayed-coincidence method. However, their error bars are wider than

Table 7. Comparison of relative (R) and absolute (A) transition probabilities (in 10^8 s^{-1}) of 4p levels. References: A, Adams and Whaling (1981), the errors (in parenthesis) are standard errors (in the last decimal(s)); B, Danzmann and Kock (1982), the errors are one standard deviation; C, Garcia and Campos (1985); D, this work, length formulation, Vujnović and Wiese (1992), the errors are two standard deviations. The error in the last digit of the experimental (A-C) branching ratios and transition probabilities is shown in parentheses, while in the case of the absolute values in column E percentage errors (Er) are given.

States		$\lambda_{\text{obs}} (\text{\AA})^a$	A [†]		B		C		D		E	
Upper	Lower		R	R	R	R	R	A	R	A	A	Er (%)
$3p^4(^3P)4p^4P_{3/2}$	$3p^4(^3P)3d^4D_{5/2}$	4371.3	0.388(3)	0.393(2)				0.223	0.380	0.223	0.221	8
	$3p^4(^3P)3d^4D_{3/2}$	4400.1	0.288(3)	0.290(1)				0.165	0.281	0.165	0.160	11
	$3p^4(^3P)3d^4D_{1/2}$	4420.9	0.057(5)	0.054(3)				0.030	0.052	0.030	0.031	11
	$3p^4(^3P)4s^4P_{3/2}$	4735.9	1	1				0.586	1	0.586	0.580	3
	$3p^4(^3P)4s^4P_{1/2}$	4933.2	0.243(3)	0.249(2)				0.141	0.241	0.141	0.144	5
	$3p^4(^3P)4s^4P_{1/2}$	5062.0	0.381(2)	0.383(1)				0.229	0.390	0.229	0.223	11
$3p^4(^3P)4p^4D_{7/2}$	$3p^4(^3P)4s^4P_{3/2}$	4348.1	6.8(5)	7.4(5)				1.188	6.97	1.188	1.171	4
	$3p^4(^3P)3d^4F_{9/2}$	6643.7	1	1				0.171	1	0.171	0.147	10
	$3p^4(^3P)3d^4F_{7/2}$	10683.0	0.095(10)					0.0025	0.015			
	$3p^4(^3P)4s^2P_{3/2}$	2891.6	0.21(5)	0.214(6)				0.163	0.192	0.163	0.182	11
$3p^4(^1D)4p^2P_{1/2}$	$3p^4(^3P)4s^2P_{3/2}$	2979.1	0.48(5)	0.48(2)				0.389	0.460	0.389	0.416	11
	$3p^4(^3P)4s^2P_{1/2}$	4131.7	1	1				0.846	1	0.846	0.85	11
	$3p^4(^1D)4s^2D_{3/2}$	4474.8	0.323(3)	0.325(2)				0.309	0.365	0.309	0.290	11
	$3p^4(^3P)3d^2D_{3/2}$	2942.9	0.67(5)	0.65(2)			0.279	0.534	1.035	0.534	0.53	11
$3p^4(^1D)4p^2F_{3/2}$	$3p^4(^3P)4s^2P_{3/2}$	3033.5	0.126(5)	0.124(2)			0.085	0.077(9)	0.194	0.100	0.099	11
	$3p^4(^3P)4s^2P_{1/2}$	3766.1	0.099(4)	0.096(7)			0.108	0.098(13)	0.184	0.095	0.074	14
	$3p^4(^3P)3d^2P_{1/2}$	4237.2	0.139(2)	0.137(2)			0.203	0.184(16)	0.211	0.109	0.112	11
	$3p^4(^1D)4s^2D_{3/2}$	4277.5	1	1			1	0.907(90)	1	0.516	0.80	11
	$3p^4(^1D)4s^2D_{5/2}$	4530.6	0.0251(4)	0.0269(4)			0.047	0.042(8)	0.052	0.027	0.021	11
	$3p^4(^3P)3d^2F_{5/2}$	4598.8	0.082(3)	0.083(2)			0.127	0.115(11)	0.153	0.079	0.067	11
$3p^4(^1D)4p^2F_{5/2}$	$3p^4(^1D)4s^2D_{3/2}$	4637.2	0.335(2)	0.342(2)			0.404	0.079(5)	0.258	0.054	0.071	3
	$3p^4(^3P)3d^2D_{3/2}$	5017.2	1	1			1	0.196(20)	1	0.208	0.207	4
	$3p^4(^3P)3d^2D_{5/2}$	5176.2					0.082	0.016(2)	0.125	0.026	0.017	10
	$3p^4(^1D)3d^2G_{7/2}$	6172.3	0.92(4)	0.93(7)			0.962	0.189(20)	1.01	0.211	0.200	3
$3p^4(^1D)4p^2F_{7/2}$	$3p^4(^1D)4s^2D_{5/2}$	4609.6	1	1			1	0.759(120)	1	0.636	0.789	4
	$3p^4(^3P)3d^2F_{5/2}$	4904.8	0.044(2)	0.042(2)			0.054	0.041(7)	0.075	0.048	0.037	7
	$3p^4(^3P)3d^2D_{5/2}$	5141.8	0.099(2)	0.098(3)			0.111	0.084(14)	0.409	0.260	0.081	4
	$3p^4(^1D)3d^2G_{9/2}$	6114.9	0.235(4)	0.245(6)			0.280	0.212(5)	0.338	0.215	0.200	6

^a Norlén (1973).

those obtained with the beam-dye-laser method and do not always encompass either the beam-dye-laser results or our calculated values.

Our individual transition probabilities may be compared directly with the absolute values determined experimentally by Garcia and Campos (1985) or with the recommended values of Vujnović and Wiese (1992). Additional comparison is possible with the experimental branching ratios of Adams and Whaling (1981) and Danzmann and Kock (1982). A selection of results for transitions considered by Adams and Whaling is presented in table 7. The selection includes all multiplets for which there is overlap with the measurements of Danzmann and Kock. Some of our calculated branching ratios lie between the experimental error bars, but for others, there are substantial differences, although the deviations for the $3p^4(^1D)4p\ ^2P_{3/2}$ level are primarily due to the error in the calculated value for the transition used as reference by Adams and Whaling. If we focus on the comparison between our calculations and the absolute values given by Vujnović and Wiese (1992), it is clear that apart from transitions with small probabilities, significant discrepancies arise only for transitions involving the $3p^4(^1D)4s\ ^2D_{5/2}$ and $3p^4(^3P)3d\ ^2D_{5/2}$ levels. These two levels are particularly strongly interacting. For the transitions from $3p^4(^1D)4p\ ^2F_{7/2}$ to these two levels, CI mixing between the two levels results in cancellation in one transition (5142 Å) and an augmenting of the transition probability in the other (4610 Å). In situations such as this, relatively small changes in the CI mixing coefficients (the $\{a_i\}$ in (1)) can result in large changes in the transition probabilities. Our results for these two transitions are clearly at odds with the best experimental values (however, the agreement for the two rather weak transitions from $3p^4(^1D)4p\ ^2F_{5/2}$ is much better), indicating that our calculated mixing of the two $^2D_{5/2}$ levels is not quite accurate. This is probably because of the different *LS* symmetries of the $3p^4$ cores. As we remarked earlier, core correlation is not fully treated in these calculations. This would be a serious deficiency only when very strong mixing occurs. These transitions aside, table 7 indicates that our calculated transition probabilities (and not just the lifetimes) are in good accord with the best experimental results available.

4. Conclusions

The calculations described in this paper are the most extensive and most accurate available in the literature. The calculated lifetimes of the atomic levels agree with those determined from the cascade-free beam-dye-laser experiments to within a few per cent, where comparison is possible. The errors arising from such experiments are claimed to be less than one per cent and our calculations confirm this level of accuracy. For a few states, notably those of $^2D_{5/2}$ symmetry, the CI mixing is very strong and our calculations for transitions involving these levels are seen not to be so reliable as the others. Further theoretical work on these interactions would be desirable. Experimental data at 1% accuracy remains sparse, and there is clearly a need for additional experimental work of this quality.

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