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Theoretical Study of Transition Probabilities and Stark Broadening Parameters and of Several Spectral Lines with Astrophysical Interest of Double-ionized Thallium

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Abstract

Leckrone et al. reported the presence of double-ionized thallium (Tl III) in the stellar atmosphere of the chemically peculiar star, χ Lupi, in 1999. Two spectral lines at 1332.3 and 1558.6 Å were detected in its stellar spectrum. Here, we claim that there are ions and lines that need further study to make possible the LTE abundance analysis once improved atomic data is available. In this sense, Tl III is included in the ions list that requires improved atomic data. To contribute to the solution of this problem, an analysis of the atomic parameters of the double-ionized thallium is presented here. In this work, calculations of transition probabilities were made to obtain values of the theoretical radiative lifetimes and theoretical Stark parameters for widths and shifts of 22 spectral lines of Tl III. Relativistic Hartree–Fock calculations using Cowan's code allowed us to obtain the required transition probabilities. In our calculations, the core polarization effects were included. Later, the Griem semiempirical approach was used to obtain the Stark parameters. Our lifetimes values for 10 levels were compared with the experimental ones. In this paper, we discuss the behavior of the Stark parameters versus the temperature of three relevant spectral lines. Stark width values of the isoelectronic sequence Tl III–Pb IV are also displayed.

Key words: atomic data – atomic processes

1. Introduction

The applications of Tl III in the chemical industry are well known: inorganic thallium (III) salts are Lewis acids, and can react as typical electrophiles with unsaturated organic substrates such as olefins (McKillopp 2009). In 1999 (Leckrone et al. 1999), the Tl III spectral lines of 1332.3 and 1558.6 Å were detected in the stellar atmosphere of the star, χ Lupi. Leckrone et al. claimed that there were ions and lines that needed further study to make the LTE abundance analysis possible once the improved atomic data are available. The Tl III was included in the ions list that requires improved atomic data. To solve this, a study of the atomic data of the Tl III is presented in this work. The calculation of the probabilities of transition is not enough for this analysis. We believe that a study of the Stark Broadening parameters is necessary, because in the stellar atmospheres of A- and B-type stars, the collision with electrons is the basic mechanism of widening of the spectral lines (Popović et al. 1999). This analysis is relevant to understand the possible problems derived from the overlap between spectral lines in these atmospheres.

Au I, Hg II, Tl III, Pb IV, and Bi V are isoelectronic ions. Previously, Alonso-Medina et al. (2010) studied the Pb IV atomic parameters; that study included some of the authors of the present work. A similar one is presented here.

Twenty-two spectral lines of Tl III were found by McLennan et al. (1929). Although the number of lines studied was extended in an interesting paper by Gutmann & Crooker (1973), which was a continuation of the unpublished Gutmann Ph.D. thesis of 1969, only the 22 spectral lines mentioned above are presented in the NIST database (Kramida et al. 2018).

Several theoretical works on the probabilities of transition of Tl III can be found here in the bibliography. The oscillator strengths for the sharp, principal, and diffuse series, as well as the lifetimes of the lowest excited states in the spectra of Tl III, were calculated (Migdałek 1976). Transition amplitudes for two lines of Tl III were calculated in Chou & Johnson (1997). In 2000, oscillator strengths for seven spectral lines were obtained (Migdalek & Gamulewicz 2000). Safronova & Johnson (2004) calculated oscillator strengths for transitions in au-like ions. Later, oscillator strengths for the 1558.6 and 1266.2 Å spectral lines of Tl III were calculated (Głowacki & Migdałek 2009).

Fortunately, there are experimental values of Tl III lifetime levels performed by several authors (Lindgård et al. 1982; Poulsen et al. 1982). The lifetime of $5d^{10}6p\ ^2P^{\circ}_{3/2}$ was measured by Andersen et al. (1972). Lifetime values for 10 levels, including the $5d^{10}6p\ ^2P^{\circ}_{3/2}$ level, of Tl III were measured later by Henderson et al. (1997). There are Stark broadening calculations for two Tl III multiplets that were obtained by Dimitrijević & Sahal-Bréchot (1998) by using a semiclassical-perturbation formalism (Sahal-Bréchot 1969a, 1969b; Sahal-Bréchot et al. 2014).

In this work, we present theoretical values of atomic parameters for 22 spectral lines of the Tl III that are displayed in the NIST database and that arise from configurations $5d^{10}\,ns$ ($n = 7, 8$), $5d^{10}\,np$ ($n = 6, 7$), $5d^{10}\,nd$ ($n = 6, 7$), $5d^{10}\,5f$, and $5d^{10}\,5g$. Our theoretical radiative lifetimes for 10 levels are compared with the experimental values presented in the bibliography. These calculations are similar to those made for Bi IV by Colón et al. (2017).

In Section 2 we present our theoretical calculations. The Stark widths and shifts parameters are presented for an electronic density of 10^{17} cm^{-3} and several temperatures. To test our results, we present calculated values of the spectral line widths corresponding to the multiplets $5d^96s6p$–$5d^96p^2$ and $5d^96s^2$–$5d^96s7p$, which are compared with the values obtained by Dimitrijević & Sahal-Bréchot (1998).

Our results are described in Section 3. Five tables of values, together with a figure displaying regularities of the Stark broadening parameters versus the temperature, are presented. A comparison of Stark parameters of Tl III and Pb IV is also displayed.

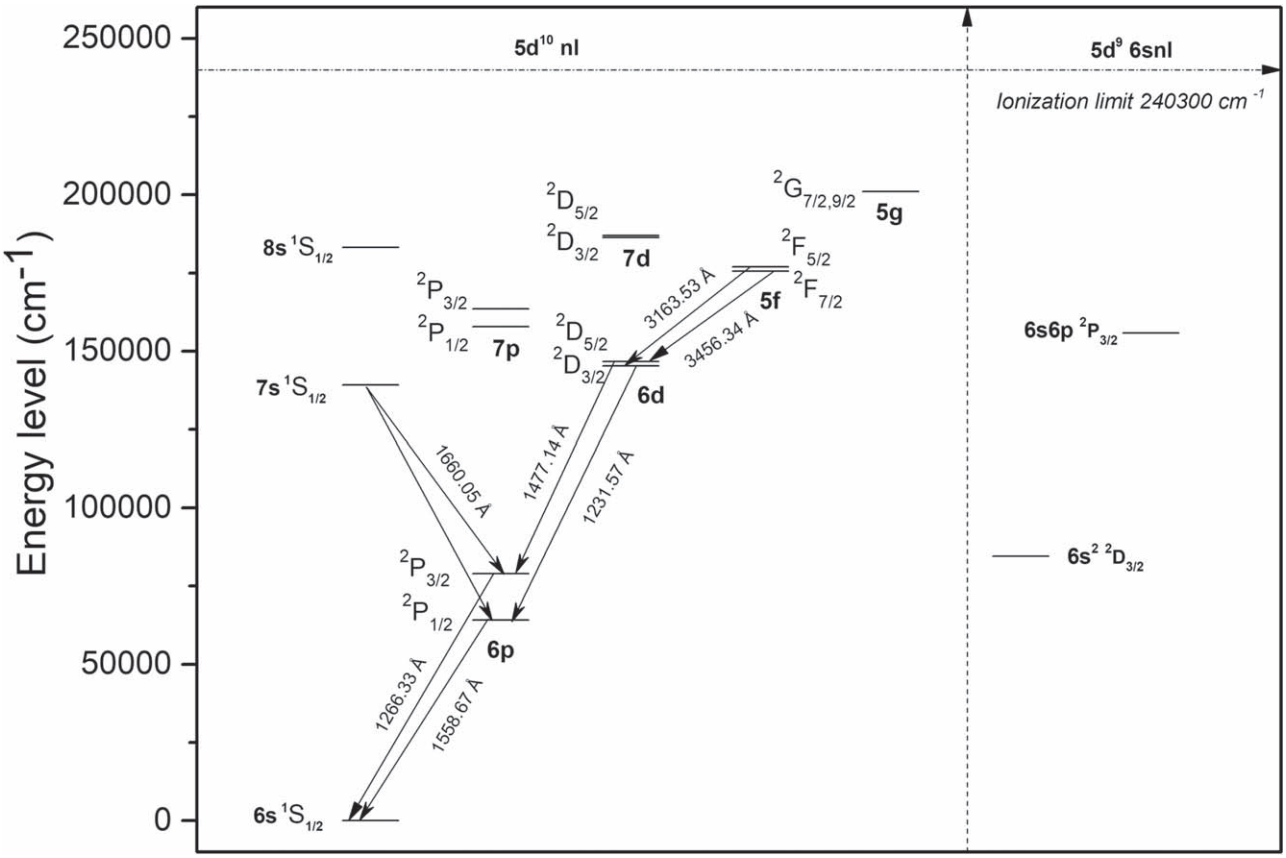

Figure 1. Tl III Partial Gotrian diagram with energy levels published by Moore (1958). Spectral lines with experimental lifetime in the bibliography are shown.

2. Theoretical Calculations

Wave functions and transition probabilities were calculated by means of the Cowan computer code (Cowan 1981). This code employs relativistic Hartree–Fock (HFR) calculations in an intermediate coupling scheme (IC) to obtain the results. Using a modification in a similar way to that used in the works mentioned above, we included in our calculations the core polarization effects (CPE). The CP effects were included using the expressions of Migdalek & Baylis (1978) and of Biémont et al. (2000).

Following the suggestions of these authors, the matrix element was modified to take into account the potential change. Also, we introduced the core penetration term suggested by Hameed in 1972. In this way, the $\langle Pnl|r|Pn'l'\rangle$ is replaced by

$$\int_0^\infty P_{nl} r\left(1 - \frac{\alpha_d}{(r^2 + r_c^2)^{3/2}}\right) P_{n'l'}\, dr - \frac{\alpha_d}{r_c^3}\int_0^{r_c} P_{nl}(r) r P_{n'l'}(r) dr. \quad (1)$$

The values for dipole polarizability and cut-off radius computed by Migdalek & Gamulewicz (2000) were used: $\alpha_d = 5.472$ (in au) and $r_c = 1.349$ (in au).

Twenty eight configurations of Tl III were used in our calculations: $5d^{10}ns$ ($n = 6$–10), $5d^{10}nd$ ($n = 6$–9), $5d^{10}ng$ ($n = 5$, 7), $5d^96s^2$, $5d^96s7s$, $5d^96s6d$, and $5d^96p^2$ for even parity and $5d^{10}np$ ($n = 6$, 8), $5d^{10}nf$ ($n = 5$–7), $5d^{10}nh$ ($n = 6$–8), $5d^96s6p$, $5d^96s7p$, and $5d^97s6p$ for odd parity. For IC, the calculations we used were all the experimental levels shown in the Moore table (Moore 1958), based on McLennan et al. (1929). Although we also considered the configurations and energy levels of Gutmann & Crooker (1973), we chose not to force the adjustment of those levels beyond 3%. Too many levels that are very close in energy (in many cases, with differences less than 1%) require a great adjustment effort that can also negatively influence the results of the transition probabilities. As is well known, the over-adjustment of the energy levels may involve residual values of wave functions with an excessive and nonexperimental influence on the values of the transition probabilities. A partial Gotrian energy levels scheme of the Tl III showing the adjusted levels and spectral lines is displayed in Figure 1. Only spectral lines with experimental lifetimes in the bibliography are displayed in this figure.

As we mentioned above, we have allowed our theoretical levels to differ by 1% from the experimental levels of Moore, and by 3% in the levels of Gutmann to exclude an excessive influence of a forced mixture of configurations in the transitions probabilities. The parameters obtained following this procedure and taking into account the Cowan suggestions about the parameters number adjusted, do not differ by more than 10% of the ab initio values, and are available on request.

Later, to calculate the Stark broadening parameters, we used the semiempirical impact approximation obtained by Griem (1968). This approach was obtained taking into account Baranger's original formulation (Baranger 1958). For this

Table 1
Radiative Lifetimes Calculated of Several Levels of the Tl III

Level	Radiative Lifetimes τ (*ns*)				
	This Work			Other Authors	
	Ab Initio	Without CPE	With CPE	Experimental[a]	Theoretical
$5d^{10}6p\ ^2P^o_{1/2}$	3.47	3.34	2.76	1.95 ± 0.06	1.05[a]
$5d^{10}6p\ ^2P^o_{3/2}$	1.97	1.80	1.49	1.06 ± 0.04 0.75 ± 0.08[b]	0.57[a]
$5d^{10}6d\ ^2D_{3/2}$	0.58	0.49	0.46	0.54 ± 0.06	0.33[a]
$5d^{10}6d\ ^2D_{5/2}$	0.92	0.79	0.74	0.71 ± 0.03	0.53[a]
$5d^{10}7s\ ^2S_{1/2}$	0.64	0.57	0.57	0.83 ± 0.09	0.57[a]
$5d^{10}7p\ ^2P^o_{1/2}$	5.97	3.73	4.80	0.98 ± 0.12	1.60[a] 6.26[d]
$5d^{10}7p\ ^2P^o_{3/2}$	1.72	1.29	0.70	0.97 ± 0.06	0.21[a] 1.82[d]
$5d^{10}7d\ ^2D_{5/2}$	2.49	2.37	2.85	3.02 ± 0.26	1.44[a] 1.35[d]
$5d^{10}5f\ ^2F^o_{5/2}$	2.40	1.72	1.50	0.41 ± 0.10 1.00 ± 0.30[c]	1.44[a] 1.35[d]
$5d^{10}5f\ ^2F^o_{7/2}$	2.34	2.55	2.41	4.92 ± 0.50	2.01[a] 2.32[d]

Notes.
[a] Henderson et al. (1997).
[b] Andersen et al. (1972).
[c] Poulsen et al. (1982).
[d] Migdałek (1976).

purpose. we used the following expressions:

$$\varpi_{se} \approx 8\left(\frac{\pi}{3}\right)^{3/2}\frac{\hbar}{ma_0}N_e\left(\frac{E_H}{kT}\right)^{1/2} \times\left[\sum_{i'}|\langle i'|\ \boldsymbol{r}\ |i\rangle|^2 g_{se}\left(\frac{E}{\Delta E_{i'i}}\right) + \sum_{f'}|\langle f'|\ \boldsymbol{r}\ |f\rangle|^2 g_{se}\left(\frac{E}{\Delta E_{f'f}}\right)\right], \quad (2)$$

$$d \approx -8\left(\frac{\pi}{3}\right)^{3/2}\frac{\hbar}{ma_0}N_e\left(\frac{E_H}{kT}\right)^{1/2} \times\left[\sum_{i'}\left(\frac{\Delta E_{i'i}}{|\Delta E_{i'i}|}\right)|\langle i'|\ \boldsymbol{r}\ |i\rangle|^2 g_{sh}\left(\frac{E}{\Delta E_{i'i}}\right) - \sum_{f'}\left(\frac{\Delta E_{f'f}}{|\Delta E_{f'f}|}\right)|\langle f'|\ \boldsymbol{r}\ |f\rangle|^2 g_{sh}\left(\frac{E}{\Delta E_{f'f}}\right)\right], \quad (3)$$

where, d and ω_{se} represent the Stark line shifts and width (half-width at half-maximum; HWHM), respectively, in angular frequency units, $E = 3/2$ kT is the energy of the perturbing electron, $E_{\rm H}$ is the hydrogen ionization energy, N_e is the free electron density, and T is the electron temperature. The initial and final levels of the transitions are denoted by i and f, respectively.

As seen in previous works by these same authors (Colón et al. 2017; de Andrés-García et al. 2018), we use the effective Gaunt factor, g_{se} and g_{sh} proposed by Seaton (1962) and Van Regemorter (1962). A factor larger than 1.5 between calculated and experimental values can be expected with the use of the effective Gaunt factor (Griem 1968). As can be seen in the expressions, we need to obtain a set of matrix elements, including all relevant transitions. Although several authors use the Coulomb approximation for this purpose, we use the matrix elements previously obtained with the Cowan code (Cowan 1981), which provides a complete set of transition probabilities: lines allowed in LS coupling and the so-called forbidden transitions.

To provide values in units of wavelength, we used the expression $\omega = \omega_{se}\ \lambda^2/(\pi c)$, where ω is the FWHM, λ is the wavelength, and c is the light speed, to transform the units of angular frequency obtained in the Griem's expressions.

3. Results and Discussion

We cannot compare in this work our values of the transition probabilities with other theoretical values present in the bibliography since the probabilities of transition are very sensitive to different methods and they can differ when dealing with different approaches.

To test the transition probabilities obtained in this work and used in the Stark broadening calculations, our theoretical lifetimes of 10 levels that have experimental measurements are presented in Table 1. With the exception of the experimental lifetimes of levels $5d^{10}7p\ ^2P^o_{3/2}$ and $5d^{10}5f\ ^2F^o_{7/2}$, the ratio between the experimental values of radiative lives and the theoretical values obtained in this work is less than 1.5. In addition, the theoretical lifetimes of these two aforementioned levels presented by others authors are close with our theoretical values. For these reasons we think that the values of the transition probabilities obtained in this work are a good basis for the calculation of the Stark broadening.

All of our results for the atomic data are shown in Tables 2–4. In the first three columns, we present the identification of the spectral lines studied: transition array, multiplet, and wavelengths (in Å). The transition probabilities are presented in the fourth column. In the last columns, the Stark line width and the Stark line shift are displayed (in Å) (a negative shift is toward the blue).

The theoretical values for the Stark broadening of spectral lines of 1349.44 and 622.69 Å are presented in Table 5. These spectral lines are not in the NIST database, but are listed by Gutmann & Crooker (1973), and correspond to the multiplets $5d^96s6p$–$5d^96p^2$

Table 2
Tl III $5d^{10}$ *ns* ($n = 7, 8$) and $5d^{10}$ *np* ($n = 6, 7$) Theoretical Transition Probabilities $A_{ij}(10^8\ s^{-1})$ and Line Widths (FWHM), ω (Å), and Shifts, d (Å), Normalized to $Ne = 10^{17}\ cm^{-3}$

Transition Array	Multiplet	λ(Å)[a]	$A_{ij}(10^8\ s^{-1})$	T (10^4 K)	ω (Å)	d (Å)
$5d^{10}6p$–$5d^{10}$ 7 s	$^2P^\circ_{1/2}$–$^2S_{1/2}$	1332.36	8.70	1	0.05	−0.04
				2	0.02	−0.01
				3	0.02	−0.01
				5	0.02	−0.02
				10	0.03	−0.02
				16	0.03	−0.02
$5d^{10}$ 6p–$5d^{10}$ 7 s	$^2P^\circ_{3/2}$–$^2S_{1/2}$	1660.05	8.85	1	0.09	−0.07
				2	0.04	−0.03
				3	0.04	−0.02
				5	0.04	−0.03
				10	0.04	−0.04
				16	0.05	−0.04
$5d^{10}$ 7p–$5d^{10}$ 8 s	$^2P^\circ_{1/2}$–$^2S_{1/2}$	3946.02	1.46	1	2.32	−1.44
				2	2.11	−1.76
				3	1.96	−1.53
				5	2.02	−1.41
				10	1.92	−1.22
				16	1.78	−1.09
$5d^{10}$ 7p–$5d^{10}$ 8 s	$^2P^\circ_{3/2}$–$^2S_{1/2}$	5086.99	1.04	1	4.21	−1.78
				2	3.79	−3.02
				3	3.47	−2.84
				5	3.64	−2.63
				10	3.50	−2.29
				16	3.30	−2.06
$5d^{10}$ 6s–$5d^{10}$ 6p	$^2S_{1/2}$–$^2P^\circ_{3/2}$	1266.33	6.69	1	0.02	−0.02
				2	0.01	−0.01
				3	0.01	−0.01
				5	0.01	−0.01
				10	0.01	−0.01
				16	0.01	−0.01
$5d^{10}$ 6s–$5d^{10}$ 6p	$^2S_{1/2}$–$^2P^\circ_{1/2}$	1558.67	3.62	1	0.02	−0.01
				2	0.01	−0.01
				3	0.01	−0.01
				5	0.01	−0.01
				10	0.01	−0.01
				16	0.01	−0.01
$5d^{10}$ 7s–$5d^{10}$ 7p	$^2S_{1/2}$–$^2P^\circ_{3/2}$	4109.85	1.58	1	1.27	−0.80
				2	0.62	−0.31
				3	0.43	−0.19
				5	0.67	−0.30
				10	0.80	−0.38
				16	0.84	−0.39
$5d^{10}$ 7s–$5d^{10}$ 7p	$^2S_{1/2}$–$^2P^\circ_{1/2}$	5362.40	0.98	1	0.63	0.48
				2	0.26	−0.15
				3	0.21	−0.12
				5	0.33	−0.27
				10	0.40	−0.36
				16	0.41	−0.36
$5d^{10}$ 6d–$5d^{10}$ 7p	$^2D_{3/2}$–$^2P^\circ_{3/2}$	5499.40	0.08	1	3.49	−1.82
				2	1.93	−1.13
				3	1.08	−0.46
				5	1.77	−0.91
				10	2.14	−1.23
				16	2.26	−1.27
$5d^{10}$ 6d–$5d^{10}$ 7p	$^2D_{5/2}$–$^2P^\circ_{3/2}$	5927.8	0.57	1	3.49	−1.82
				2	1.93	−1.13
				3	1.08	−0.46
				5	1.77	−0.91
				10	2.14	−1.23

Table 2
(Continued)

Transition Array	Multiplet	λ(Å)[a]	$A_{ij}(10^8\ s^{-1})$	T (10^4 K)	ω (Å)	d (Å)
				16	2.26	−1.27
$5d^{10}$ 6d–$5d^{10}$ 7p	$^2D_{3/2}$–$^2P^o_{1/2}$	8001	0.34	1	4.03	−1.83
				2	2.34	−1.49
				3	1.36	−0.11
				5	2.06	−0.56
				10	2.54	−1.06
				16	2.66	−1.14

Note. A negative shift is toward the blue.
[a] Kramida et al. (2018).

Table 3
Tl III $5d^{10}$ *n*d (n = 6, 7) Theoretical Transition Probabilities $A_{ij}(10^8\ s^{-1})$ and Line Widths (FWHM), ω (Å), and Shifts, d (Å), Normalized to $Ne = 10^{17}\ cm^{-3}$

Transition Array	Multiplet	λ(Å)[a]	$A_{ij}(10^8\ s^{-1})$	T (10^4 K)	ω (Å)	d (Å)
$5d^{10}$ 6p–$5d^{10}$ 6d	$^2P^o_{1/2}$–$^2D_{3/2}$	1231.57	19.70	1	0.05	−0.04
				2	0.03	−0.03
				3	0.02	−0.01
				5	0.03	−0.02
				10	0.03	−0.03
				16	0.03	−0.03
$5d^{10}$ 6p–$5d^{10}$ 6d	$^2P^o_{3/2}$–$^2D_{5/2}$	1477.14	13.50	1	0.12	−0.09
				2	0.07	−0.05
				3	0.04	−0.02
				5	0.06	−0.04
				10	0.06	−0.06
				16	0.07	−0.06
$5d^{10}$ 6p–$5d^{10}$ 6d	$^2P^o_{3/2}$–$^2D_{3/2}$	1506.37	2.15	1	0.09	−0.07
				2	0.06	−0.04
				3	0.04	−0.02
				5	0.04	−0.03
				10	0.05	−0.04
				16	0.05	−0.04
$5d^{10}$ 7p–$5d^{10}$ 7d	$^2P^o_{1/2}$–$^2D_{3/2}$	3507.41	3.39	1	2.45	0.49
				2	2.48	0.03
				3	2.32	0.01
				5	2.39	−0.02
				10	2.28	−0.05
				16	2.11	−0.05
$5d^{10}$ 7p–$5d^{10}$ 7d	$^2P^o_{3/2}$–$^2D_{5/2}$	4269.91	1.63	1	3.76	−1.41
				2	3.68	−2.23
				3	3.45	−2.38
				5	3.76	−2.19
				10	3.71	−1.91
				16	3.52	−1.71
$5d^{10}$ 7p–$5d^{10}$ 7d	$^2P^o_{3/2}$–$^2D_{3/2}$	4380.57	0.25	1	4.22	0.54
				2	4.08	−0.16
				3	3.77	−0.21
				5	3.94	−0.25
				10	3.78	−0.27
				16	3.54	−0.27

Note. A positive shift is red.
[a] Kramida et al. (2018).

and $5d^96s^2$–$5d^96s7p$ with Stark broadening parameters calculated by Dimitrijević & Sahal-Bréchot (1998). Our values for the cited lines are compared with the values of Dimitrijević & Sahal-Bréchot (1998) in the last two columns of Table 5. As can be seen, there is good agreement within the margins of the approximations used; as we mentioned above, a factor larger than 1.5 between the calculated and experimental values can be expected with the use of this effective Gaunt factor (Griem 1968).

Table 4
Tl III $5d^{10}$ 5f and $5d^{10}$ 5g Theoretical Transition Probabilities $A_{ij}(10^8\ s^{-1})$ and Line Widths (FWHM), ω (Å), and Shifts d (Å), Normalized to $Ne = 10^{17}\ cm^{-3}$

Transition Array	Multiplet	λ(Å)[a]	$A_{ij}(10^8\ s^{-1})$	T (10^4 K)	ω (Å)	d (Å)
$5d^{10}$ 6d–$5d^{10}$ 5f	$^2D_{3/2}$–$^2F^\circ_{5/2}$	3163.53	2.80	1	0.91	−0.73
				2	0.61	−0.33
				3	0.26	−0.20
				5	0.43	−0.29
				10	0.54	0.36
				16	0.57	−0.37
$5d^{10}$ 6d–$5d^{10}$ 5f	$^2D_{5/2}$–$^2F^\circ_{5/2}$	3300.80	0.19	1	1.16	−0.69
				2	0.75	−0.41
				3	0.30	−0.21
				5	0.55	−0.37
				10	0.69	−0.48
				16	0.73	−0.49
$5d^{10}$ 6d–$5d^{10}$ 5f	$^2D_{5/2}$–$^2F^\circ_{7/2}$	3456.34	3.77	1	1.78	−1.04
				2	1.18	−0.66
				3	0.48	−0.38
				5	0.90	−0.63
				10	1.14	−0.78
				16	1.19	−0.79
$5d^{10}$ 5f–$5d^{10}$ 5g	$^2F^\circ_{7/2}$–$^2G_{9/2}$	3933.65	3.54	1	6.28	−3.60
				2	7.60	−3.27
				3	7.07	−3.40
				5	7.79	−3.10
				10	7.75	−2.64
				16	7.33	−2.34
$5d^{10}$ 5f–$5d^{10}$ 5g	$^2F^\circ_{5/2}$–$^2G_{7/2}$	4155.75	0.13	1	5.99	−3.37
				2	7.03	−3.04
				3	6.40	−3.12
				5	7.14	−2.88
				10	7.15	−2.50
				16	6.79	−2.22

Note. A positive shift is red.
[a] Kramida et al. (2018).

Table 5
Tl III $5d^9$ 6s6p–$5d^9$ $6p^2$ and $5d^9$ $6s^2$–$5d^9$ 6s7p Line Widths (FWHM), ω (Å), and Shifts d (Å), Normalized to $Ne = 10^{17}\ cm^{-3}$

Transition Array	Multiplet°	λ(Å)[a]	T (10^4 K)	ω (Å)	
				This work	Dimitrijević & Sahal-Bréchot (1998)
$5d^9$ 6s6p–$5d^9$ $6p^2$	$(3)_{5/2}$–$(1)_{5/2}$	1349.44	2	0.0300	0.0170
			5	0.0210	0.0110
			10	0.0078	0.0082
$5d^9$ $6s^2$–$5d^9$ 6s7p	$^2D_{5/2}$–$(3)_{3/2}$	622.69	2	0.0120	0.0099
			5	0.0083	0.0074
			10	0.0080	0.0063

Note.
[a] Gutmann & Crooker (1973).

A study of theoretical trends of Stark widths FWHM (ω (pm)) and Stark line shifts (d(pm)) versus the temperature for 1266.33, 1477.14, and 3163.53 Å lines are presented in Figure 2. In Figure 3, the behavior of the Stark width for two transitions of Tl III and Pb IV versus the atomic number, Z, is displayed. In the case of Pb IV, the values used were calculated in a previous study following a similar procedure to the one used in the present work (see Alonso-Medina et al. 2010).

Transition probabilities and Stark widths and shifts of 22+2 Tl III spectral lines were calculated in this work. In addition, radiative lifetimes of 10 levels of Tl III were calculated and compared with experimental values. In our calculations, we considered the CPE by including a modification in the Cowan code. The semiempirical approach of Griem allowed us to obtain the Stark broadening of widths and shifts parameters. The theoretical behavior of these values with the temperature and with the charge number Z has been studied.

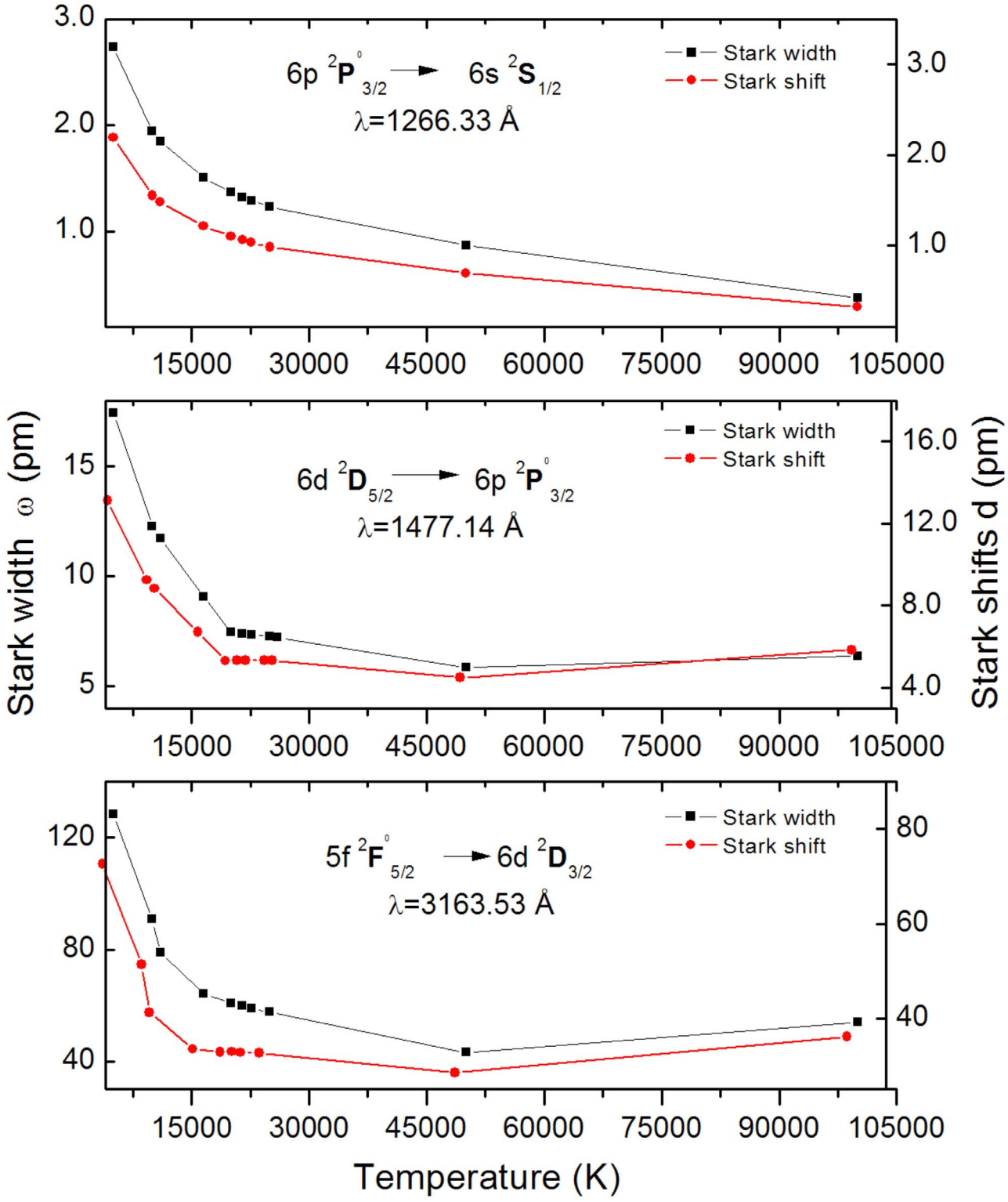

Figure 2. Calculated Stark width FWHM (ω(pm)) and absolute value of shift (d(pm)) at an electron density of 10^{17} cm^{-3} vs. temperature for several spectral lines of Tl III.

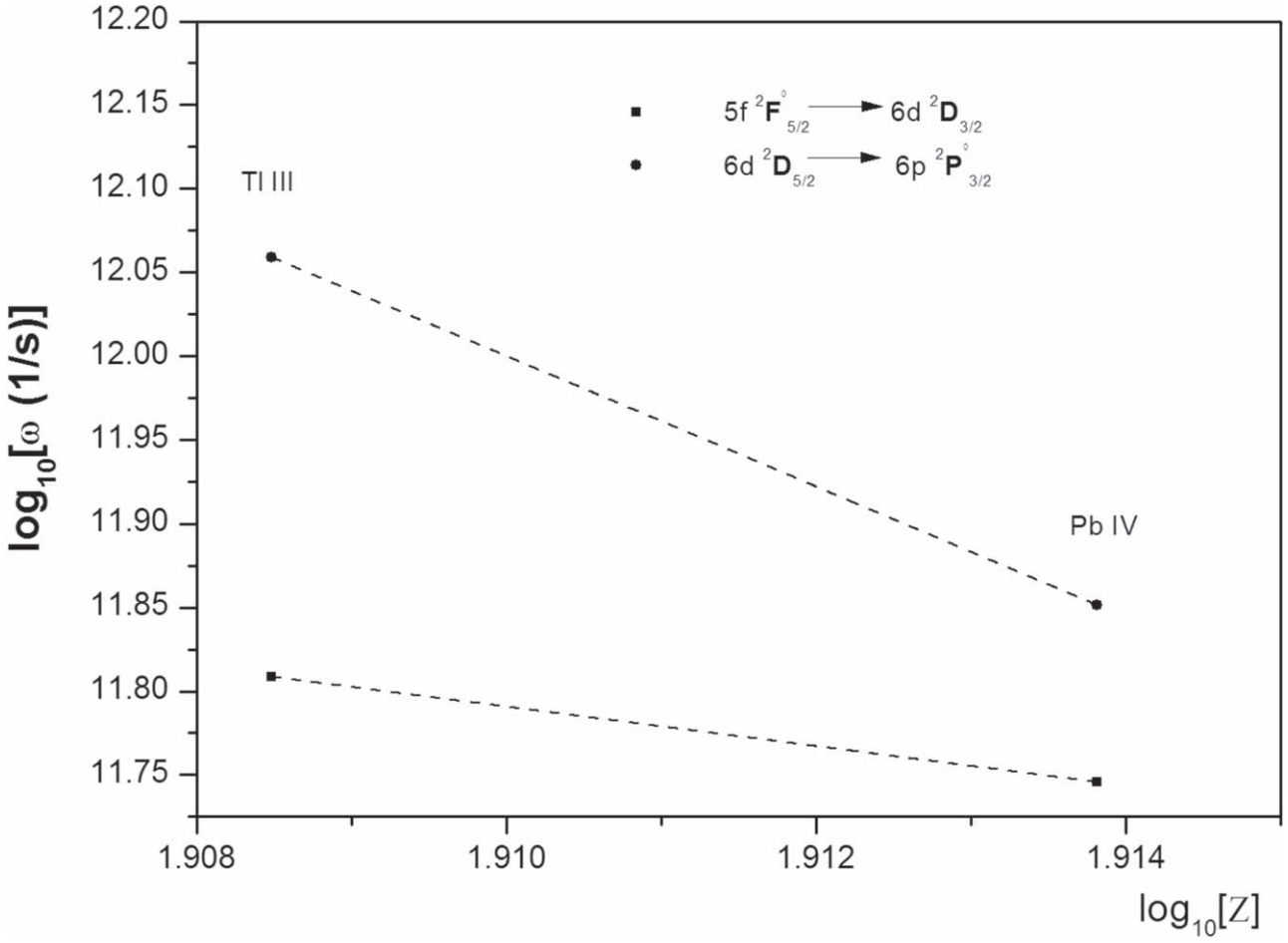

Figure 3. Theoretical Stark width FWHM (ω (in frequency units)) of two transitions at a electron density of 10^{17} cm^{-3} in Tl III (present work) and Pb IV (Alonso-Medina et al. 2010) vs. the ion charge (number Z) at a temperature of 20,000 K.

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