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Radiative recombination rate coefficients for highly-charged tungsten ions

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ABSTRACT

Partial and total radiative recombination rate coefficients are presented for highly-charged ions of tungsten with closed shells, W^{28+}, W^{38+}, W^{46+}, W^{56+}, W^{64+}, W^{70+}, and W^{72+}, as well as for the H-like ion W^{73+} and the bare nucleus W^{74+}. The temperature range 10^3–10^{10} K is considered. Calculations have been performed in the framework of the fully relativistic Dirac–Fock treatment of photoionization and radiative recombination processes taking into account all significant multipoles of the radiation field. We assess the influence of multipole effects on recombination rate coefficients as compared with the commonly used dipole approximation. For the first time, we show that the relativistic Maxwell–Boltzmann distribution of continuum electrons should be used at high temperature. This decreases the rate coefficient significantly compared to the nonrelativistic distribution.

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Contents

1. Introduction

Radiative recombination rate coefficients along with photoionization and radiative recombination cross sections are required for estimates of ionization equilibria and thermal balance in terrestrial and astrophysical plasmas contaminated by various ions. In fusion reactors, impurity ions of heavy elements up to tungsten may be present. Data on highly-charged tungsten ions are important in the performance of future fusion devices developed, for example, in the framework of the Tungsten Program [1].

A number of calculations exist for photoionization cross sections (PCS) and radiative recombination cross sections (RRCS) as well as for radiative recombination rate coefficients for ions of elements with atomic number $Z \leqslant 54$ [2–11]. However, there are few calculations of PCS and RRCS for ions as heavy as tungsten [10,11]. As to the recombination rate coefficients for tungsten ions, data for three ions obtained using an approximate theoretical method are presented in Ref. [5] at four values of temperature in the range $1 \leqslant k_B T \leqslant 30$ keV (k_B is the Boltzmann constant and T is the temperature). Because tungsten impurities are deeply involved in fusion studies and atomic data on ionization–recombination coefficients are currently unavailable [1], we present the partial and total recombination rate coefficients for nine highly-charged ions of tungsten from the Pd-like ion W^{28+} to the bare nucleus W^{74+}. The wide range of temperatures $0.09\text{ eV} \lesssim k_B T \lesssim 900\text{ keV}$ is considered. We have used a fully relativistic treatment of photoionization and radiative recombination processes. Electron wavefunctions were found in the framework of the Dirac–Fock (DF) method with proper consideration of the exchange interaction between electrons. All significant multipole orders of the radiation field were taken into account.

As is well known (see, for example, Refs. [11–14] and references therein), the multipole and relativistic effects are of great importance in consideration of photoionization and radiative recombination at high electron energies, especially for heavy and highly-charged ions. In particular, as has been noted in Ref. [11], the difference between the relativistic calculation of RRCS with regard to all multipoles and the nonrelativistic calculation within the dipole approximation for the $1s, 2p$, and $3d$ shells of uranium is 10–18% even at electron kinetic energy as low as $E_k = 10$ eV and may exceed an order of magnitude at $E_k = 1000$ keV.

Nevertheless, the multipole and certain relativistic effects are usually neglected in consideration of photoionization and radiative recombination processes in plasmas. For example, in Ref. [7], the electric dipole approximation is used while the electron energy range up to 100 keV is considered. The electric dipole approximation is also adopted in a recent paper [8] where recombination rate coefficients for isoelectronic sequences to the Na-like one for Z = 1–30, 36, 42, and 54 are presented. The highest electron energy under consideration is equal to 1.36 Z^2 keV, which is to say that for $Z = 54$, $E_k \approx 4000$ keV. The widely used tables [2] of hydrogenic recombination rate coefficients were calculated within the nonrelativistic dipole approximation for temperatures up to $T = \infty$.

To find recombination rate coefficients for such high temperatures, it is necessary to have the RRCS or PCS values at very high energies up to several thousand keV. Usually, asymptotic values of PCS are used in the simple nonrelativistic form $\sigma_{ph}^{(i)} \propto k^{-(3.5+\ell_i)}$ ($\sigma_{ph}^{(i)}$ is the PCS for the ith shell, k is the photon energy, and ℓ_i is the orbital momentum) [6,8]. However, as will be shown below, this asymptotic form is not adequate in the case of the relativistic PCS calculation including all multipoles.

As to relativistic effects, calculations [3,7,8] have been carried out using semi-relativistic corrections. However, in determining RRCS, the majority of calculations commonly use the nonrelativistic expression for the transformation coefficient between PCS and RRCS which may result in erroneous values of RRCS and recombination rate coefficients at high electron energies. We show here, for the first time, the relativistic correction factor to the expression for the recombination rate coefficient arising from treatment of the relativistic Maxwell–Boltzmann distribution of continuum electrons instead of the commonly adopted nonrelativistic one. The factor depends on temperature and may change the recombination rate coefficients by several multiples at high temperatures.

Given the aforesaid observations, it is important to assess the contribution of nondipole effects and the impact of the proper asymptotic behavior of the relativistic cross sections with regard to all multipoles as well as the specific relativistic effects in a calculation of recombination rate coefficients for various ions. In this paper, we consider the influence of the following effects on recombination rate coefficients and relevant cross sections: (i) the relativistic transformation coefficient between PCS and RRCS; (ii) the relativistic factor in the expression for the recombination rate coefficient; (iii) taking into account multipole effects; and (iv) the proper asymptotic behavior of the relativistic PCS with regard to all multipoles. These effects are shown to play an essential role in calculations of PCS and RRCS, and, ultimately, of recombination rate coefficients, altering the results considerably at high electron energies. Preliminary results concerning points (i)–(iii) were presented recently [9].

In Section 2, we present the expressions for PCS and RRCS as well as derive the relativistic correction factor for the recombination rate coefficient expression. In Section 3, we discuss the results obtained for ions of tungsten along with ions of other representative elements to demonstrate that our conclusions are generally applicable. We also compare our results with other calculations. Partial and total recombination rate coefficients for tungsten ions presented in Table 1 were calculated including the influence of these effects. The total rate coefficient is the sum of the partial ones over all atomic shells with principal quantum number $n \leqslant 20$. Partial recombination rate coefficients are given for shells with $n \leqslant 12$ and orbital quantum number $\ell \leqslant 6$ which contribute more than ~70% of a total rate coefficient.

2. Method of calculation

The partial PCS in the ith subshell per one electron involved in the rate coefficient calculation can be written as

$$\sigma_{\rm ph}^{(i)} = \frac{4\pi^2\alpha}{\tilde{k}(2j_i+1)}\sum_L\sum_\kappa\Big[(2L+1)Q_{LL}^2(\kappa)+LQ_{L+1L}^2(\kappa) +(L+1)Q_{L-1L}^2(\kappa)-2\sqrt{L(L+1)}Q_{L-1L}(\kappa)Q_{L+1L}(\kappa)\Big]. \quad (1)$$

We use relativistic units ($\hbar = m_0 = c = 1$) in Eqs. (1)–(5). Here $\tilde{k} = k/m_0c^2$ is the photon energy, α is the fine structure constant, L is the multipolarity of the radiation field, the relativistic quantum number $\kappa = (\ell - j)(2j+1)$, ℓ and j are the orbital and total angular momenta of the electron, and $Q_{\Lambda L}(\kappa)$ is the reduced matrix element which is written in the form

$$Q_{\Lambda L}(\kappa) = \left([\bar{\ell}][\ell_i]/[\Lambda]\right)^{1/2} C^{\Lambda 0}_{\bar{\ell}0\ell_i0}\mathcal{A}\begin{pmatrix}\bar{\ell} & 1/2 & j\\ \ell_i & 1/2 & j_i\\ \Lambda & 1 & L\end{pmatrix}R_{1\Lambda} + \left([\ell][\bar{\ell}_i]/[\Lambda]\right)^{1/2} C^{\Lambda 0}_{\ell 0\bar{\ell}_i0}\mathcal{A}\begin{pmatrix}\ell & 1/2 & j\\ \bar{\ell}_i & 1/2 & j_i\\ \Lambda & 1 & L\end{pmatrix}R_{2\Lambda}. \quad (2)$$

Here $\bar{\ell} = 2j - \ell$, $C^{\Lambda 0}_{\ell_1 0\ell_2 0}$ is the Clebsch–Gordan coefficient, $\mathcal{A}$ is the recoupling coefficient for the four angular momenta, $[a]$ denotes the expression $(2a+1)$, and $R_{1\Lambda}$ and $R_{2\Lambda}$ are the following radial integrals

$$R_{1\Lambda} = \int_0^\infty G_i(r)F(\widetilde{E}_k, r)j_\Lambda(\tilde{k}r)dr,$$
$$R_{2\Lambda} = \int_0^\infty G(\widetilde{E}_k, r)F_i(r)j_\Lambda(\tilde{k}r)dr. \quad (3)$$

In Eq. (3), $j_\Lambda(\tilde{k}r)$ is the spherical Bessel function of the Λth order, G and F are the large and small components of the Dirac electron wavefunction multiplied by r, and $\widetilde{E}_k = E_k/m_0c^2$ is the kinetic electron energy. In Eqs. (1)–(3), the subscript i is related to the bound electron while designations with no subscript are related to the continuum electron state. Electron wavefunctions are calculated by the DF method with inclusion of the exact exchange between bound electrons as well as between bound and free electrons [15]. The finite nuclear size is taken into account. Both bound and continuum wavefunctions are calculated in the self-consistent field of the corresponding ions with $N+1$ and N electrons, respectively.

The subshell RRCS of the recombination process accompanied by the capture of an electron with energy $\widetilde{E}_k$ to the ith subshell of the ion with N electrons is expressed in terms of the corresponding PCS as follows.

$$\sigma_{\rm rr}^{(i)} = Aq_i\sigma_{\rm ph}^{(i)}, \quad (4)$$

where q_i is the number of vacancies in the ith subshell prior to recombination. The transformation coefficient A can be derived from the principle of detailed balance. The exact relativistic expression for the coefficient has the following form [11,14]

$$A_{\rm rel} = \frac{\tilde{k}^2}{2\widetilde{E}_k + \widetilde{E}_k^2}. \quad (5)$$

However, in the majority of calculations [5–10], the coefficient is used in the form

$$A = \frac{k^2}{2m_0c^2E_k}, \quad (6)$$

which was obtained in the nonrelativistic approximation.

The difference between $\sigma_{\rm rr}^{(i)}$ obtained with Eqs. (5) and (6) depends on the electron energy E_k only and can be written as

$$\frac{A - A_{\rm rel}}{A_{\rm rel}} = \frac{E_k}{2m_0c^2}. \quad (7)$$

As is evident, the difference is equal to $\sim 10\%$ at $E_k = 100$ keV and reaches ~100% at 1000 keV. Consequently, the relativistic transformation coefficient must be used in the RRCS calculation at high energies.

The relativistic recombination rate coefficient $\alpha_{\rm rel}^{(i)}(T)$ can be found using the thermal average over the fully relativistic RRCS, the continuum electron velocity being described by the relativistic Maxwell–Boltzmann distribution function $f(E)$ normalized to unity as follows [16]

$$f(E)dE = \frac{E(E^2-1)^{1/2}}{\theta e^{1/\theta}K_2(1/\theta)} \times e^{-(E-1)/\theta}\,dE. \quad (8)$$

Here E is the total electron energy in units of m_0c^2 including the rest energy and $\theta = k_{\rm B}T/m_0c^2$ is the characteristic dimensionless temperature. The function K_2 denotes the modified Bessel function of the second order. Taking into account the relativistic distribution in the form of Eq. (8) and the transformation coefficient $A_{\rm rel}$ (Eq.(5)), we have for the relativistic radiative recombination rate coefficient

$$\alpha_{\rm rel}^{(i)}(T) = \langle v\sigma_{\rm rr}^{(i)}\rangle = F_{\rm rel}(\theta)\cdot\alpha^{(i)}(T). \quad (9)$$

Here $v = (p/E)c$ is the electron velocity with the momentum $p = \sqrt{E^2-1}$ and $\alpha^{(i)}(T)$ is the usual recombination rate coefficient with nonrelativistic Maxwell–Boltzmann electron distribution which may be written as

$$\alpha^{(i)}(T) = (2/\pi)^{1/2}c^{-2}(m_0k_{\rm B}T)^{-3/2}q_i\int_{\varepsilon_i}^\infty k^2\sigma_{\rm ph}^{(i)}(k)e^{(\varepsilon_i-k)/(k_{\rm B}T)}\,dk, \quad (10)$$

where ε_i is the binding energy of the ith shell. Eq. (10) is equivalent to Eq. (2) from Ref. [4]. In Eq. (9), $F_{\rm rel}(\theta)$ is the relativistic factor which has the form

$$F_{\rm rel}(\theta) = \sqrt{\frac{\pi}{2}\theta}\Big/K_2(1/\theta)e^{1/\theta}. \quad (11)$$

This is just the factor which has been disregarded in all previous calculations.

One may easily obtain an approximate expression for the relativistic factor $F_{\rm rel}(\theta)$ using the asymptotic expansion of the Bessel function $K_2(1/\theta)$ at large $1/\theta$ [17], that is, at low temperature. The approximate expression can be written as

$$\widetilde{F}_{\rm rel}(\theta) = 1\Big/\left(1 + \frac{15}{8}\theta + \frac{105}{128}\theta^2 + \cdots\right). \quad (12)$$

As will be shown below, Eq. (12) provides an excellent approximation for $F_{\rm rel}(\theta)$ with the terms through order θ^2 at $\theta \lesssim 1$.

The integral in Eq. (10) was calculated by the use of the five-point Newton–Coates quadrature formula at temperature $T \lesssim 10^8$ K. At higher temperature for rapid convergence of the integral, we calculated the integral written in the form proposed by Nahar and Pradhan [18]

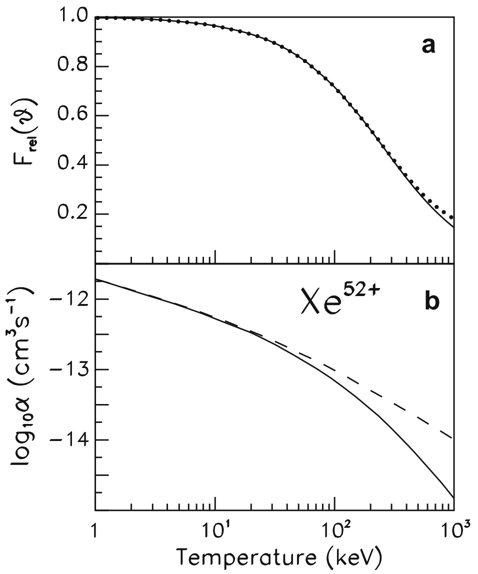

Fig. 1. (a) The exact relativistic radiative recombination rate coefficient factor $F_{\rm rel}(\theta)$ (solid) and the approximate factor $\widetilde{F}_{\rm rel}(\theta)$ (dotted); (b) rate coefficients $\alpha^{(2s)}(T)$ with (solid) and without (dashed) regard to the relativistic factor (Eq. (9)) for recombination of the 2*s* electron with the Xe^{52+} ion.

$$\alpha^{(i)}(T) = (2/\pi)^{1/2} c^{-2} (m_0 k_{\rm B} T)^{-3/2} q_i \int_0^1 (\varepsilon_i - k_{\rm B} T \ln x)^2 \sigma^{(i)}_{\rm ph}(k) dx. \quad (13)$$

The integral in Eq. (13) was estimated using Gaussian quadrature with 40 nodes and refined with 80 nodes [19]. The integration was terminated if the difference between the integral values obtained was less than a prescribed accuracy. If the integral was calculated with an insufficient accuracy, the integration interval was reduced and the integral was recalculated. Then the rest of the interval was estimated. This method turns out to be efficient and provides the accuracy required in the calculations.

The majority of the recombination rate coefficients in Table 1 were calculated with an accuracy better than 1%. In the worst cases (outer shells and highest temperatures), the accuracy is $\lesssim 5\%$.

3. Results and discussion

3.1. Relativistic factor for the radiative rate coefficient

It follows from Eq. (11) that the relativistic factor for the recombination rate coefficient depends only on temperature. The *T*-dependence of the factor is demonstrated in Fig. 1(a). As is seen, the factor $F_{\rm rel}(\theta)$ differs noticeably from unity beginning at several tens of keV. Adopting the relativistic distribution of continuum electrons instead of the nonrelativistic one results in a decrease of the rate coefficient values by a factor of 1.2 at plasma temperature $k_{\rm B}T = 50$ keV and up to a factor of 7 at $k_{\rm B}T = 1000$ keV. It should be noted that the widely used tables of hydrogenic recombination rate coefficients tabulated for temperatures up to $T = \infty$ were calculated for the nonrelativistic Maxwell distribution [2].

We also compare the exact relativistic factor $F_{\rm rel}(\theta)$ (the solid curve in Fig. 1(a)) and the approximate one $\widetilde{F}_{\rm rel}(\theta)$ (the dotted curve). As can be seen, there is little difference between the two curves. The approximate and exact values of the factor differ by ~4% at $k_{\rm B}T = 500$ keV and 25% at $k_{\rm B}T = 1000$ keV.

To gain a better illustration, we display in Fig. 1(b) the recombination rate coefficients obtained with (solid curve) and without (dashed) the relativistic factor for recombination of the 2*s* electron with the He-like ion of Xe. One can see that inclusion of the relativistic factor changes $\alpha^{(2s)}(T)$ considerably at high temperatures.

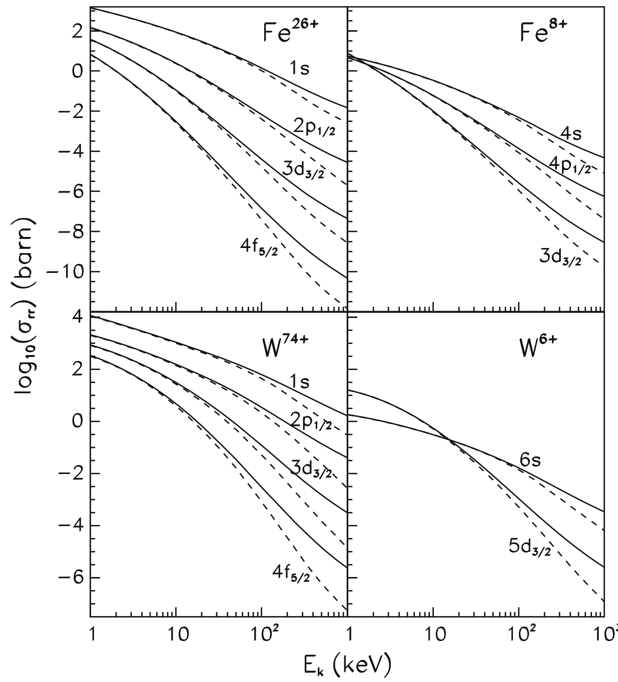

Fig. 2. Subshell radiative recombination cross sections (in barns) calculated taking into account all multipoles *L* (solid) and within the electric dipole approximation (dashed) as a function of the electron energy E_k.

3.2. Multipole effects

The electric dipole approximation involves only terms with $L = 1$ in Eq. (1). In this case according to selection rules (see Eq. (2)), the associated values of κ are equal to $\kappa_i - 1, -\kappa_i$, and $\kappa_i + 1$ where κ_i refers to the *i*th shell. As is well known, the dipole approximation in PCS calculations holds at low electron energy E_k but breaks down at a higher energy (see, for example, Refs. [12,13] and references therein). Let us assess the impact of nondipole effects on RRCS and recombination rate coefficients for various highly-charged ions.

In Fig. 2, we compare RRCS obtained by the DF method in the electric dipole approximation $\sigma_{\rm rr}$(dip) (dashed curves) with RRCS calculated with allowance made for all necessary multipoles $\sigma_{\rm rr}(L)$ (solid curves) for various ions of Fe and W. The electron energy range under consideration is $1 \leqslant E_k \leqslant 1000$ keV. Magnitudes of the percent difference between the two calculations

$$\Delta_{\rm dip} = \frac{\sigma_{\rm rr}(L) - \sigma_{\rm rr}({\rm dip})}{\sigma_{\rm rr}(L)} \times 100\% \quad (14)$$

are given in Table A for bare nuclei of a number of elements.

As illustrated in Fig. 2, the solid and dashed curves begin to diverge noticeably even at several keV. At the highest energy, 1000 keV, in the case of W^{74+}, $\sigma_{\rm rr}$(dip) is smaller than the exact value $\sigma_{\rm rr}(L)$ by ~5 times for the 1*s* shell and by ~40 times for the $4f_{5/2}$ subshell. As shown in Table A, the dipole approximation differs from the exact calculation by ~3% to 20% at $E_k = 10$ keV, ~15% to 50% at $E_k = 50$ keV, and ~100% (by several multiples in reality) at $E_k = 1000$ keV. The dependence of $\Delta_{\rm dip}$ on the orbital quantum number ℓ_i of the shell under consideration is shown to be noticeable, $\Delta_{\rm dip}$ being larger with increasing ℓ_i. The difference $\Delta_{\rm dip}$ increases slightly with *Z* at low energies $E_k \lesssim 10$ keV and does not depend on *Z* at higher energies. We list in Table A shells with

Table A
Difference $\Delta_{\rm dip}$ (in %) between RRCS calculated taking into account all multipoles $\sigma_{\rm rr}(L)$ and within the dipole approximation $\sigma_{\rm rr}({\rm dip})$ (see Eq. (14)) for bare nuclei.

E_k (keV)	1s shell				$2p_{1/2}$ shell				$3d_{3/2}$ shell				$4f_{5/2}$ shell			
	Ne	Fe	Xe	W	Ne	Fe	Xe	W	Ne	Fe	Xe	W	Ne	Fe	Xe	W
0.01	0.1	0.7	2.9	5.2	0.1	0.7	2.6	4.3	0.1	0.6	2.5	4.5	0.1	0.6	2.5	4.6
1	0.4	1.0	3.2	5.4	0.7	1.2	3.1	4.8	1.1	1.6	3.5	5.5	1.7	2.2	4.0	6.0
10	3.2	3.8	5.8	7.9	5.6	6.2	7.7	8.9	10	10	12	13	15	15	16	18
50	15	15	17	18	24	24	25	24	38	38	38	38	51	52	52	52
100	27	27	28	29	40	40	40	39	58	58	57	57	75	73	73	73
500	75	74	74	72	84	84	84	82	89	89	90	90	97	95	95	95
1000	83	83	82	82	92	93	93	93	93	94	95	95	98	97	97	98

Table B
The number of multipoles L taken into account in the present calculation of $\sigma_{\rm ph}$ for the W^{73+} ion.

E_k (keV)	$1s$	$2p_{1/2}$	$3d_{3/2}$	$4f_{5/2}$
10	5	6	8	10
50	6	7	10	12
100	7	8	11	14
500	13	16	21	26
1000	19	24	31	37

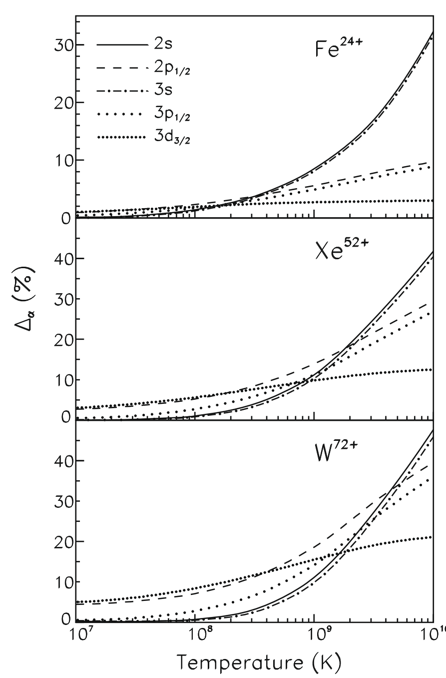

Fig. 3. Difference Δ_α (see Eq. (15)) between rate coefficients calculated with regard to all significant multipoles and in the dipole approximation for recombination of the $2s$, $2p_{1/2}$, $3s$, $3p_{1/2}$, and $3d_{3/2}$ electrons with He-like ions.

$j = \ell - 1/2$ only because there is approximately the same difference for shells with $j = \ell + 1/2$. As demonstrated in Fig. 2, the difference is scarcely affected by the ion charge and the principal quantum number n_i of the shell. There is practically the same difference $\Delta_{\rm dip}$, for example, for recombination of the 1s electron with the bare nucleus of W and for recombination of the 6s electron with the many-electron ion W^{6+} as well as for recombination of the $3d_{3/2}$ ($2p_{1/2}$) electron with the bare nucleus of Fe and the $3d_{3/2}$ ($4p_{1/2}$) electron with the ion Fe^{8+}.

The results presented show that RRCS obtained within the dipole approximation are inaccurate at high energies. Table B demonstrates how many multipoles must be taken into consideration for various shells of the ion W^{73+} at various electron energies to achieve the accuracy of $\sim 0.01\%$ prescribed in our PCS calculations.

From the aforesaid, it may be assumed that the dipole approximation will also fail in the calculation of recombination rate coefficients at high temperature. In Fig. 3, we present the percent difference between the exact $\alpha^{(i)}(L)$ and dipole $\alpha^{(i)}({\rm dip})$ values of the rate coefficient which may be written as

$$\Delta_\alpha = \frac{\alpha^{(i)}(L) - \alpha^{(i)}({\rm dip})}{\alpha^{(i)}(L)} \times 100\%. \qquad (15)$$

The difference is given for recombination of the $2s, 2p_{1/2}, 3s, 3p_{1/2}$, and $3d_{3/2}$ electrons with the He-like ions Fe^{24+}, Xe^{52+}, and W^{72+}. These shells are the lowest ones making significant contribution to total rate coefficients. As evident from the figure, the difference Δ_α is larger for heavy elements. The inclusion of higher multipoles may change partial rate coefficients by $\sim$7% at a temperature of $T = 10^8$ K, by $\sim$20% at $T = 10^9$ K, and by $\sim$50% at $T = 10^{10}$ K for W^{72+}. This shows that at high temperature, total recombination rate coefficients obtained within the dipole approximation will be considerably smaller than accurate values obtained using all multipoles L, all other approximations being the same.

3.3. Asymptotic values of photoionization cross sections at high energy

Another problem in the rate coefficient calculation is associated with the necessity to involve PCS or RRCS at high electron energy. Because the proper PCS calculation at high energy is a difficult task, many authors match asymptotic values. Usually the well-known asymptotic expression is involved [6,8] which has been derived

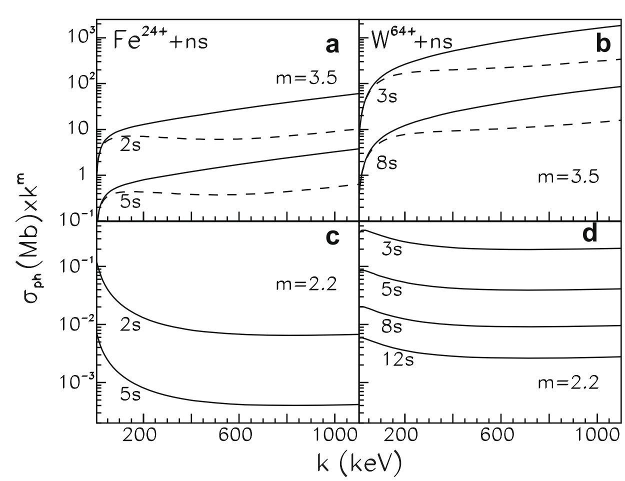

Fig. 4. Photoionization cross sections $\sigma_{\rm ph}^{(ns)}$ multiplied by k^m where $m = 3.5$ ((a) and (b)) and $m = 2.2$ ((c) and (d)) for the ns shells of Fe and W ions. Solid lines show the DF calculation having regard to all multipoles L and dashed lines show results for the DF dipole approximation.

in the framework of the nonrelativistic dipole approximation and can be written as follows [20],

$$\sigma_{ph}^{(i)} \sim k^{-(3.5+\ell_i)}. \tag{16}$$

However, Eq. (16) breaks down for the asymptotic behavior of the relativistic PCS. Both the relativistic and multipole effects contribute to the asymptotic behavior. In Fig. 4, we present the product $\sigma_{ph}^{(ns)} \times k^m$ for ions $Fe^{23+}: 1s^2ns$ and W^{63+} : [Ne]ns involving PCS for the ns-electrons with various n. The DF calculations of $\sigma_{ph}^{(ns)}$ were carried out with allowance made for all L (solid curves) and within the electric dipole approximation (dashed curves). As is seen, the solid curves have no asymptote in the whole photon energy range $100 \leqslant k \leqslant 1100$ keV with $m = 3.5$ (Fig. 4(a) and (b)). The dashed curves reach an approximate asymptote at the photon energy $k \approx 100$–150 keV. However this asymptote has little in common with exact values of the product considered as is evident from a comparison of solid and dashed curves.

In Fig. 4(c) and (d), the product $\sigma_{ph}^{(ns)} \times k^{2.2}$ is shown. The value $m = 2.2$ was obtained through fitting of the $\sigma_{ph}^{(ns)}$ values at lower energies. In this case, the solid curves associated with relativistic calculations including all multipoles reach a rather good asymptote at high energies $k \approx 500$–600 keV. As shown, this asymptotic behavior holds for various ns shells ($2 \leqslant n \leqslant 12$) as well as for different elements and different ions. It should be noted that the asymptotic behavior $\sigma_{ph}^{(ns)} \propto k^{-2.2}$ obtained in the present work correlates well with the energy-dependence $\sigma_{ph}(k)$ for the 1s shell of the hydrogen-like, high-Z ions presented by Bethe and Salpeter [21]. They demonstrated that in the relativistic case, $\sigma_{ph}^{(1s)} \propto k^{-m}$ where m varies almost monotonically from $m \approx 2.7$ to $m = 1$ at the ultra-relativistic limit, never taking the value $m = 3.5$.

Consequently, we may say that adoption of the PCS asymptote in the form of Eq. (16) results in inaccurate values of $\sigma_{ph}^{(i)}$ and $\sigma_{rr}^{(i)}$ at high E_k and, because of this, inaccurate values of $\alpha^{(i)}(T)$ at high T. In the present work, the values of $\sigma_{ph}^{(i)}$ involved in Eq. (10) were found without using an approximate analytical asymptote by direct DF calculations up to the electron energy $E_k \gtrsim 7000$ keV for the s, p, and d electrons and to several hundred keV for shells with larger orbital angular momenta (or less if the PCS decrease rapidly as E_k increases). In a few cases we have extrapolate PCS using the Lagrange four-point formula to obtain values at higher energies.

3.4. Comparison with other calculations

In Table C we present our calculated PCS compared with the corresponding results by Ichihara and Eichler [11] and Badnell [8] for the 1s shell of the H-like ion Xe^{53+}. In each case, we give $\sigma_{ph}^{(1s)}$ for those values of E_k which are presented by the other authors. Our results were obtained just for these energies. The percent difference Δ between the PCS obtained in the present work and by the other authors is written as follows,

$$\Delta = \frac{\sigma_{ph}^{(i)}(\text{present}) - \sigma_{ph}^{(i)}(\text{other})}{\sigma_{ph}^{(i)}(\text{present})} \times 100\%. \tag{17}$$

The case of an one-electron ion is particularly convenient for checking the influence of the higher multipoles and the method of calculation because the ion is free from any inter-electron interactions. Also, the results obtained in the velocity and length gauge coincide for a one-electron ion.

As is evident, our calculations are in excellent agreement over the wide range of electron energy 1 eV $\leqslant E_k \leqslant 6000$ keV with the values from a relativistic calculation [11] where all multipoles were included. In each case, our values of $\sigma_{ph}^{(i)}$ coincide with an accuracy of three significant digits with the results given in Ref. [11]. The maximum difference between the two calculations is ~1% at the highest energy $E_k = 6000$ keV.

In contrast, PCS obtained by Badnell exceed our values by ~16% in the energy range $E_k \lesssim 4$ keV and become smaller at higher energies, decreasing by approximately a factor of 8 at $E_k \approx 1800$ keV and a factor of ~30 at $E_k \approx 4000$ keV. The comparison of our PCS calculation for $\sigma_{ph}^{(2s)}$ with results by Badnell for the comparatively light ion Fe^{23+} presented in Table D reveals a similar tendency, but smaller in magnitude at low energies. The reason for the difference at low energies is not clear. It is possible that this is the influence of methods of calculation used in Ref. [8]. However, the difference at higher energies is likely due to a combination of ne-

Table D
Comparison of our calculated PCS with results by Badnell [8] for the 2s shell of the Li-like ion Fe^{23+}.

E_k (keV)	σ_{ph} (Mb)		Δ(%)
	Badnell	Present	
0.001646	2.487(−2)	2.380(−2)	−4.5
0.01646	2.451(−2)	2.345(−2)	−4.5
0.07836	2.306(−2)	2.210(−2)	−4.3
0.3605	1.778(−2)	1.712(−2)	−3.8
0.7836	1.259(−2)	1.218(−2)	−3.4
1.646	7.002(−3)	6.822(−3)	−2.6
7.836	6.582(−4)	6.491(−4)	−1.4
16.46	1.263(−4)	1.245(−4)	−1.4
78.36	1.782(−6)	1.801(−6)	1.0
164.6	1.821(−7)	1.969(−7)	7.5
360.5	1.471(−8)	1.989(−8)	26
783.6	1.134(−9)	2.784(−9)	59

Table C
Comparison of our calculated PCS with results by Ichihara and Eichler [11] and by Badnell [8] for the 1s shell of the H-like ion Xe^{53+}.

E_k (keV)	σ_{ph} (Mb)		E_k (keV)	σ_{ph} (Mb)		Δ(%)
	Ichihara and Eichler	Present		Badnell	Present	
0.001	1.94(−3)	1.94(−3)	0.00083	2.246(−3)	1.937(−3)	−16
0.004	1.94(−3)	1.94(−3)	0.00397	2.245(−3)	1.937(−3)	−16
0.04	1.94(−3)	1.94(−3)	0.03967	2.240(−3)	1.935(−3)	−16
0.2	1.92(−3)	1.92(−3)	0.1824	2.218(−3)	1.918(−3)	−16
0.4	1.89(−3)	1.89(−3)	0.3967	2.186(−3)	1.892(−3)	−16
2.	1.71(−3)	1.71(−3)	1.824	1.938(−3)	1.732(−3)	−15
4.	1.52(−3)	1.52(−3)	3.967	1.734(−3)	1.523(−3)	−14
40.	3.08(−4)	3.08(−4)	39.67	3.256(−4)	3.114(−4)	−4.5
80.	9.94(−5)	9.94(−5)	83.31	9.095(−5)	9.206(−5)	1.2
200.	1.40(−5)	1.41(−5)	182.4	1.539(−5)	1.740(−5)	12
400.	2.75(−6)	2.75(−6)	396.7	1.894(−6)	2.802(−6)	32
800.	5.97(−7)	5.97(−7)	833.1	2.071(−7)	5.495(−7)	62
2000.	1.13(−7)	1.13(−7)	1824.	1.730(−8)	1.318(−7)	87
4000.	4.07(−8)	4.07(−8)	3967.	1.350(−9)	4.117(−8)	97
6000.	2.39(−8)	2.36(−8)				

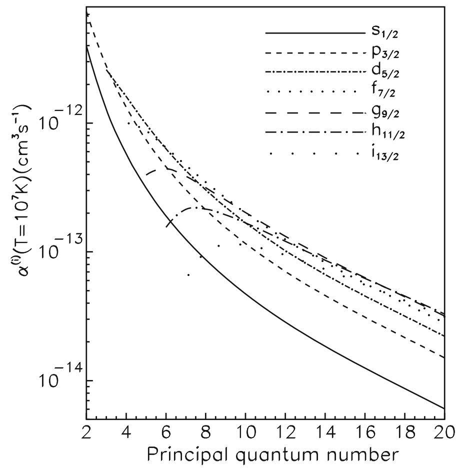

Fig. 5. Partial rate coefficients $\alpha^{(i)}$ versus the principal quantum number n for recombination of electrons into various states with the ion W^{72+} at $T = 10^7$ K.

glect of the higher multipoles and the semi-relativistic approximation used in Ref. [8].

Our total recombination rate coefficients for the tungsten ions W^{74+}, W^{64+}, and W^{56+} were compared with results by Kim and Pratt [5] obtained in the framework of an approximate method using cross sections for the bremsstrahlung "tip" region together with only a few direct calculations of RRCS. The authors performed relativistic Dirac–Slater calculations of the RRCS with regard to all multipoles. All other cross sections for each state $n\kappa$ were obtained by interpolation using the quantum defect method. Although an approximate approach was used in Ref. [5], the comparison revealed a reasonably good agreement between the two calculations. The difference ranged from 3% to 11% (depending on the temperature) for the bare nucleus and from 16% to 36% for the Ar-like ion. Clearly the relativistic factor $F_{\rm rel}(\theta)$ (Eq. (11)) was not included in Ref. [5]. At the maximum temperature under consideration $k_{\rm B}T = 30$ keV, $F_{\rm rel}(\theta) = 0.9$.

3.5. Radiative rate coefficients for tungsten ions

Rate coefficients are given in Table 1 for recombination of an electron with the following ions of tungsten: the bare nucleus W^{74+}, the H-like ion W^{73+}, and for seven ions with closed shells – the He-like ion W^{72+}, the Be-like ion W^{70+}, the Ne-like ion W^{64+},

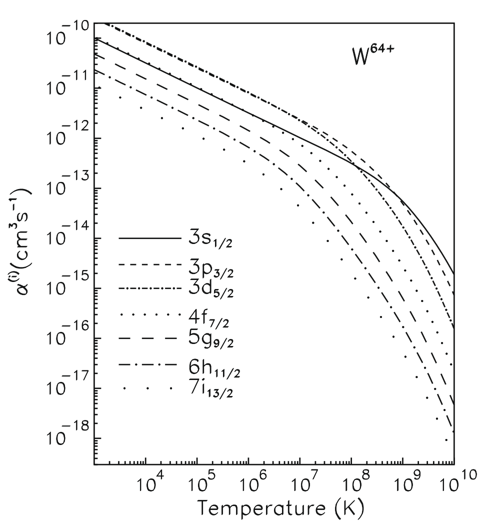

Fig. 6. Partial rate coefficients $\alpha^{(i)}$ versus temperature T for recombination of electrons into various states with the ion W^{64+}.

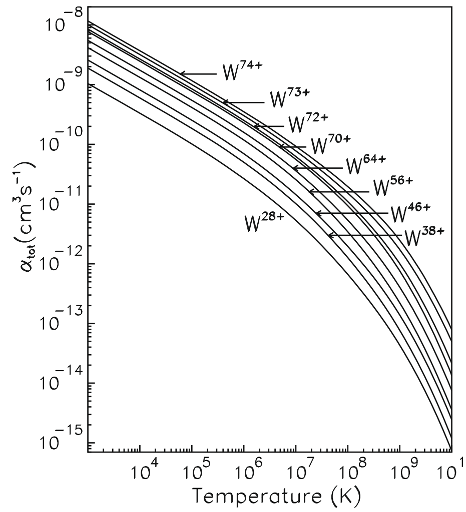

Fig. 7. Total radiative recombination rate coefficients $\alpha_{\rm tot}$ for the tungsten ions under consideration.

the Ar-like ion W^{56+}, the Ni-like ion W^{46+} having the most stable electron configuration $[\text{Kr}]3d^4_{3/2}3d^6_{5/2}$ [10], the Kr-like ion W^{38+}, and the Pd-like ion W^{28+}. Fifteen values of temperature in the range $10^3 \leqslant T \leqslant 10^{10}$ K are considered. Relativistic DF calculations were performed using expressions and methods described above.

The partial recombination rate coefficients $\alpha^{(i)}_{\rm rel}$ (below $\alpha^{(i)}$) are presented in Table 1 for electron states with $n \leqslant 12$ and $\ell \leqslant 6$ as well as the total recombination rate coefficients which are written as

$$\alpha_{\rm tot} = \sum_{i \equiv n\kappa} \alpha^{(i)}. \tag{18}$$

The summation in Eq. (18) was extended over all electron states with $n \leqslant 20$ and all possible relativistic quantum numbers $\kappa = \mp 1, \mp 2, \ldots - n$. Electron states with $n > 20$ were not taken into account because in a real plasma, there is a cutoff of bound levels from density effects, above which recombination is not meaningful. For fusion plasmas with electron density in the range of $10^{14}/\text{cm}^3$, the upper limit on the principal quantum number is $n \lesssim 20$.

We present the partial rate coefficients for high electron shells because their magnitudes are sometimes larger or comparable to those for lower shells. In Fig. 5, partial rate coefficients $\alpha^{(i)}$ are shown versus the principal quantum number n for shells with various orbital angular momenta $0 \leqslant \ell \leqslant 6$. The data are given for the ion W^{72+} and for the temperature $T = 10^7$ K. It is seen that $\alpha^{(i)}$ for shells with large ℓ are at times comparable with values for shells with smaller ℓ at the specific n and at other times exceed them. Though rate coefficients usually fall with increasing n, for shells with large ℓ, $\alpha^{(i)}$ first increases with n (see the n-dependence of the g, h, and i shells), so that a number of shells with large n and ℓ contribute considerably to $\alpha_{\rm tot}$, especially at low temperature. An example of the dependence of the partial recombination rate coefficients on temperature is displayed in Fig. 6. One can see that at $T \lesssim 10^8$ K, $\alpha^{(3p_{3/2})}$ and $\alpha^{(3d_{5/2})}$ are very close to each other and exceed $\alpha^{(3s)}$ for the more inner $3s$ shell. At $T \lesssim 10^5$ K, $\alpha^{(4f_{7/2})}$ and $\alpha^{(3s)}$ have approximately the same magnitude. As is seen from Table 1, in the case of W^{64+} and $T = 10^3$ K, the maximum contribution to $\alpha_{\rm tot}$ from the lowest $3d_{5/2}$ state is 1.02×10^{-10} cm^3/s while the contribution of the highest state presented, $12i_{13/2}$, is 1.83×10^{-11} cm^3/s (i.e., 18% of the maximum contribution). The shells presented in Table 1 contribute from 70% to 99% of the total recombination rate coefficients. In Fig. 7, $\alpha_{\rm tot}$ are presented for all tungsten ions under consideration.

4. Conclusions

We have calculated the exact relativistic DF partial and total radiative recombination rate coefficients including all significant multipoles and the relativistic factor for a wide temperature range for nine highly-charged tungsten ions which are of great current interest and for which data are not available.

For the first time, a new fully relativistic formula for the radiative recombination rate coefficient has been derived in a consistent way, that is, using relativistic expressions for PCS and for the transformation coefficient between PCS and RRCS as well as the relativistic Maxwell–Boltzmann distribution of continuum electrons instead of the nonrelativistic one adopted earlier. The formula has been factorized giving rise to the temperature-dependent relativistic correction factor for which the usual nonrelativistic expression for the rate coefficient must be multiplied. This factor has been naturally absent in all previous calculations and available databases, even though the rate coefficients have been calculated at high temperatures up to infinity.

We have shown that a contribution of multipole effects in recombination rate coefficients for highly-charged ions is significant (10–50%) at electron energies of the order of 10 keV and higher. Note that the multipole effects are neglected in the majority of plasmas calculations.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.adt.2009.08.004.

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Explanation of Table

Table 1. Radiative recombination rate coefficients.

For each ion:

Second line	Decimal logarithm of temperature T in K $(1\text{ K} = 0.8617 \times 10^{-4}\text{ eV})$
Next lines	Partial rate coefficients $\alpha_{\rm rel}^{(i)}(T)$ in cm^3 s^{-1}
Last line	Total rate coefficients $\alpha_{\rm tot}(T)$ in cm^3 s^{-1}

The decimal order is presented to the right for a recombination rate coefficient value.

Table 1
Radiative recombination rate coefficients. See page 9 for explanation of Table.

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$\boldsymbol{W^{28+}}$															
$4f_{5/2}$	8.96–11	5.04–11	2.83–11	1.59–11	8.91–12	4.92–12	2.62– 12	1.27–12	5.12–13	1.60–13	3.86–14	7.54–15	1.18–15	1.31–16	8.84–18
$4f_{7/2}$	1.17–10	6.58–11	3.70–11	2.08–11	1.16–11	6.42–12	3.42– 12	1.65–12	6.65–13	2.07–13	4.97–14	9.68–15	1.51–15	1.67–16	1.13–17
$5s_{1/2}$	4.68–12	2.64–12	1.48–12	8.35–13	4.71–13	2.68–13	1.55– 13	9.28–14	5.88–14	3.80–14	2.30–14	1.16–14	4.27–15	9.95–16	1.45–16
$5p_{1/2}$	4.54–12	2.55–12	1.44–12	8.10–13	4.58–13	2.62–13	1.54– 13	9.69–14	6.55–14	4.34–14	2.38–14	9.67–15	2.69–15	4.66–16	4.90–17
$5p_{3/2}$	1.25–11	7.05–12	3.97–12	2.23–12	1.26–12	7.17–13	4.16– 13	2.51–13	1.56–13	9.27–14	4.52–14	1.64–14	4.09–15	6.35–16	5.82–17
$5d_{3/2}$	1.51–11	8.52–12	4.79–12	2.70–12	1.53–12	8.74–13	5.12– 13	3.08–13	1.79–13	8.65–14	3.10–14	8.03–15	1.50–15	1.82–16	1.31–17
$5d_{5/2}$	2.33–11	1.31–11	7.37–12	4.15–12	2.35–12	1.34–12	7.81– 13	4.65–13	2.65–13	1.25–13	4.38–14	1.11–14	2.03–15	2.45–16	1.74–17
$5f_{5/2}$	3.23–11	1.82–11	1.03–11	5.77–12	3.24–12	1.81–12	9.88– 13	5.02–13	2.14–13	6.99–14	1.74–14	3.43–15	5.39–16	5.99–17	4.05–18
$5f_{7/2}$	4.29–11	2.42–11	1.36–11	7.65–12	4.30–12	2.40–12	1.31– 12	6.63–13	2.82–13	9.15–14	2.26–14	4.45–15	6.99–16	7.75–17	5.24–18
$5g_{7/2}$	1.52–11	8.56–12	4.82–12	2.70–12	1.49–12	7.91–13	3.82– 13	1.54–13	4.84–14	1.18–14	2.38–15	4.19–16	6.26–17	6.81–18	4.58–19
$5g_{9/2}$	1.89–11	1.06–11	5.99–12	3.35–12	1.85–12	9.83–13	4.75– 13	1.91–13	5.99–14	1.46–14	2.94–15	5.18–16	7.74–17	8.42–18	5.66–19
$6s_{1/2}$	2.37–12	1.33–12	7.51–13	4.24–13	2.39–13	1.36–13	7.85– 14	4.68–14	2.92–14	1.86–14	1.12–14	5.60–15	2.06–15	4.79–16	7.00–17
$6p_{1/2}$	2.19–12	1.23–12	6.94–13	3.91–13	2.22–13	1.27–13	7.50– 14	4.72–14	3.20–14	2.12–14	1.17–14	4.75–15	1.32–15	2.29–16	2.41–17
$6p_{3/2}$	6.25–12	3.52–12	1.98–12	1.12–12	6.31–13	3.60–13	2.09– 13	1.26–13	7.85–14	4.65–14	2.27–14	8.23–15	2.06–15	3.19–16	2.92–17
$6d_{3/2}$	7.09–12	3.99–12	2.25–12	1.27–12	7.19–13	4.14–13	2.46– 13	1.52–13	9.08–14	4.47–14	1.62–14	4.22–15	7.87–16	9.61–17	6.88–18
$6d_{5/2}$	1.11–11	6.23–12	3.51–12	1.98–12	1.12–12	6.45–13	3.81– 13	2.32–13	1.36–13	6.50–14	2.30–14	5.86–15	1.08–15	1.30–16	9.21–18
$6f_{5/2}$	1.69–11	9.53–12	5.37–12	3.03–12	1.70–12	9.60–13	5.34– 13	2.79–13	1.22–13	4.07–14	1.02–14	2.03–15	3.20–16	3.56–17	2.41–18
$6f_{7/2}$	2.26–11	1.27–11	7.16–12	4.03–12	2.27–12	1.28–12	7.11– 13	3.70–13	1.61–13	5.34–14	1.33–14	2.64–15	4.15–16	4.61–17	3.12–18
$6g_{7/2}$	1.50–11	8.46–12	4.76–12	2.67–12	1.48–12	7.86–13	3.82– 13	1.55–13	4.90–14	1.20–14	2.43–15	4.29–16	6.42–17	6.99–18	4.69–19
$6g_{9/2}$	1.87–11	1.05–11	5.92–12	3.32–12	1.83–12	9.77–13	4.75– 13	1.93–13	6.07–14	1.48–14	3.00–15	5.30–16	7.92–17	8.62–18	5.79–19
$6h_{9/2}$	4.21–12	2.37–12	1.33–12	7.42–13	4.01–13	2.00–13	8.49– 14	2.80–14	7.11–15	1.49–15	2.77–16	4.72–17	6.97–18	7.56–19	5.07–20
$6h_{11/2}$	5.05–12	2.84–12	1.60–12	8.90–13	4.80–13	2.40–13	1.02–13	3.36–14	8.52–15	1.78–15	3.32–16	5.66–17	8.35–18	9.05–19	6.07–20
$7s_{1/2}$	1.41–12	7.96–13	4.48–13	2.53–13	1.43–13	8.12–14	4.69– 14	2.77–14	1.70–14	1.07–14	6.34–15	3.17–15	1.16–15	2.70–16	3.95–17
$7p_{1/2}$	1.28–12	7.19–13	4.05–13	2.29–13	1.29–13	7.42–14	4.38– 14	2.75–14	1.84–14	1.22–14	6.69–15	2.72–15	7.56–16	1.31–16	1.37–17
$7p_{3/2}$	3.69–12	2.08–12	1.17–12	6.60–13	3.73–13	2.12–13	1.23– 13	7.41–14	4.58–14	2.70–14	1.31–14	4.76–15	1.19–15	1.84–16	1.69–17
$7d_{3/2}$	3.95–12	2.22–12	1.25–12	7.08–13	4.03–13	2.33–13	1.40– 13	8.78–14	5.30–14	2.63–14	9.58–15	2.50–15	4.68–16	5.71–17	4.09–18
$7d_{5/2}$	6.23–12	3.51–12	1.98–12	1.12–12	6.35–13	3.66–13	2.19– 13	1.35–13	7.95–14	3.85–14	1.36–14	3.49–15	6.41–16	7.73–17	5.49–18
$7f_{5/2}$	9.85–12	5.55–12	3.13–12	1.76–12	9.97–13	5.66–13	3.20– 13	1.70–13	7.58–14	2.56–14	6.46–15	1.29–15	2.03–16	2.26–17	1.53–18
$7f_{7/2}$	1.32–11	7.42–12	4.18–12	2.36–12	1.33–12	7.56–13	4.26– 13	2.26–13	1.00–13	3.35–14	8.43–15	1.67–15	2.64–16	2.93–17	1.98–18
$7g_{7/2}$	1.18–11	6.64–12	3.74–12	2.10–12	1.16–12	6.21–13	3.04– 13	1.24–13	3.93–14	9.66–15	1.96–15	3.46–16	5.18–17	5.64–18	3.79–19
$7g_{9/2}$	1.47–11	8.26–12	4.66–12	2.61–12	1.45–12	7.72–13	3.77– 13	1.54–13	4.87–14	1.20–14	2.42–15	4.28–16	6.40–17	6.97–18	4.68–19
$7h_{9/2}$	5.87–12	3.31–12	1.86–12	1.04–12	5.60–13	2.80–13	1.19– 13	3.92–14	9.96–15	2.08–15	3.88–16	6.61–17	9.75–18	1.06–18	7.09–20
$7h_{11/2}$	7.04–12	3.97–12	2.23–12	1.24–12	6.71–13	3.36–13	1.42–13	4.70–14	1.19–14	2.49–15	4.64–16	7.91–17	1.17–17	1.27–18	8.49–20
$7i_{11/2}$	1.87–12	1.05–12	5.92–13	3.27–13	1.72–13	8.09–14	3.05–14	8.71–15	1.96–15	3.80–16	6.85–17	1.15–17	1.69–18	1.83–19	1.23–20
$7i_{13/2}$	2.18–12	1.23–12	6.90–13	3.81–13	2.01–13	9.42–14	3.56–14	1.02–14	2.28–15	4.43–16	7.98–17	1.34–17	1.97–18	2.14–19	1.43–20
$8s_{1/2}$	9.23–13	5.20–13	2.93–13	1.65–13	9.35–14	5.32–14	3.06– 14	1.79–14	1.08–14	6.70–15	3.95–15	1.97–15	7.22–16	1.68–16	2.45–17
$8p_{1/2}$	8.27–13	4.66–13	2.63–13	1.48–13	8.40–14	4.81–14	2.83– 14	1.76–14	1.17–14	7.64–15	4.19–15	1.70–15	4.74–16	8.20–17	8.61–18
$8p_{3/2}$	2.39–12	1.35–12	7.61–13	4.29–13	2.43–13	1.38–13	8.01– 14	4.77–14	2.92–14	1.71–14	8.30–15	3.00–15	7.49–16	1.16–16	1.06–17
$8d_{3/2}$	2.45–12	1.38–12	7.79–13	4.41–13	2.51–13	1.46–13	8.82– 14	5.57–14	3.38–14	1.69–14	6.15–15	1.61–15	3.01–16	3.68–17	2.64–18
$8d_{5/2}$	3.90–12	2.20–12	1.24–12	7.01–13	3.99–13	2.31–13	1.39– 13	8.60–14	5.09–14	2.47–14	8.77–15	2.25–15	4.13–16	4.98–17	3.54–18
$8f_{5/2}$	6.20–12	3.49–12	1.97–12	1.11–12	6.31–13	3.61–13	2.06– 13	1.11–13	5.02–14	1.70–14	4.32–15	8.63–16	1.36–16	1.51–17	1.02–18
$8f_{7/2}$	8.32–12	4.69–12	2.65–12	1.49–12	8.47–13	4.83–13	2.76– 13	1.48–13	6.63–14	2.24–14	5.64–15	1.12–15	1.77–16	1.98–17	1.33–18
$8g_{7/2}$	8.86–12	4.99–12	2.82–12	1.58–12	8.76–13	4.70–13	2.31– 13	9.46–14	3.01–14	7.41–15	1.50–15	2.66–16	3.98–17	4.34–18	2.91–19
$8g_{9/2}$	1.10–11	6.22–12	3.51–12	1.97–12	1.09–12	5.85–13	2.87– 13	1.17–13	3.73–14	9.17–15	1.86–15	3.29–16	4.92–17	5.35–18	3.60–19
$8h_{9/2}$	5.90–12	3.32–12	1.87–12	1.04–12	5.64–13	2.82–13	1.20– 13	3.95–14	1.00–14	2.10–15	3.90–16	6.65–17	9.82–18	1.06–18	7.14–20
$8h_{11/2}$	7.07–12	3.98–12	2.24–12	1.25–12	6.76–13	3.38–13	1.43–13	4.73–14	1.20–14	2.51–15	4.67–16	7.96–17	1.18–17	1.27–18	8.55–20
$8i_{11/2}$	3.11–12	1.75–12	9.85–13	5.44–13	2.87–13	1.35–13	5.09–14	1.45–14	3.25–15	6.32–16	1.14–16	1.92–17	2.82–18	3.05–19	2.05–20
$8i_{13/2}$	3.62–12	2.04–12	1.15–12	6.34–13	3.34–13	1.57–13	5.93–14	1.69–14	3.79–15	7.37–16	1.33–16	2.23–17	3.29–18	3.56–19	2.38–20
$9s_{1/2}$	6.41–13	3.61–13	2.04–13	1.15–13	6.51–14	3.70–14	2.12– 14	1.23–14	7.33–15	4.48–15	2.63–15	1.31–15	4.79–16	1.11–16	1.62–17
$9p_{1/2}$	5.75–13	3.24–13	1.83–13	1.03–13	5.85–14	3.34–14	1.96– 14	1.20–14	7.87–15	5.12–15	2.80–15	1.14–15	3.16–16	5.48–17	5.75–18
$9p_{3/2}$	1.66–12	9.35–13	5.28–13	2.98–13	1.69–13	9.59–14	5.53– 14	3.27–14	1.98–14	1.15–14	5.58–15	2.02–15	5.03–16	7.79–17	7.13–18
$9d_{3/2}$	1.64–12	9.23–13	5.22–13	2.95–13	1.68–13	9.80–14	5.96– 14	3.78–14	2.30–14	1.15–14	4.18–15	1.10–15	2.05–16	2.51–17	1.80–18
$9d_{5/2}$	2.62–12	1.48–12	8.36–13	4.73–13	2.69–13	1.56–13	9.40– 14	5.85–14	3.46–14	1.68–14	5.98–15	1.53–15	2.81–16	3.40–17	2.41–18
$9f_{5/2}$	4.15–12	2.34–12	1.32–12	7.48–13	4.25–13	2.44–13	1.41– 13	7.68–14	3.49–14	1.19–14	3.02–15	6.04–16	9.55–17	1.06–17	7.18–19
$9f_{7/2}$	5.58–12	3.15–12	1.78–12	1.01–12	5.71–13	3.28–13	1.89– 13	1.02–13	4.61–14	1.56–14	3.95–15	7.86–16	1.24–16	1.38–17	9.33–19
$9g_{7/2}$	6.66–12	3.76–12	2.12–12	1.19–12	6.62–13	3.56–13	1.75– 13	7.21–14	2.30–14	5.66–15	1.15–15	2.03–16	3.04–17	3.32–18	2.23–19
$9g_{9/2}$	8.30–12	4.68–12	2.64–12	1.49–12	8.25–13	4.43–13	2.18– 13	8.95–14	2.85–14	7.01–15	1.42–15	2.52–16	3.76–17	4.10–18	2.75–19
$9h_{9/2}$	5.30–12	2.99–12	1.68–12	9.39–13	5.08–13	2.54–13	1.08– 13	3.56–14	9.03–15	1.89–15	3.51–16	5.99–17	8.83–18	9.58–19	6.43–20
$9h_{11/2}$	6.35–12	3.58–12	2.02–12	1.13–12	6.09–13	3.05–13	1.29–13	4.26–14	1.08–14	2.26–15	4.21–16	7.17–17	1.06–17	1.15–18	7.69–20
$9i_{11/2}$	3.55–12	2.00–12	1.13–12	6.25–13	3.29–13	1.55–13	5.84–14	1.66–14	3.73–15	7.25–16	1.31–16	2.20–17	3.23–18	3.50–19	2.35–20
$9i_{13/2}$	4.14–12	2.34–12	1.32–12	7.28–13	3.84–13	1.80–13	6.81–14	1.94–14	4.35–15	8.45–16	1.52–16	2.56–17	3.77–18	4.08–19	2.73–20
$10s_{1/2}$	4.66–13	2.62–13	1.48–13	8.38–14	4.74–14	2.69–14	1.54–14	8.85–15	5.20–15	3.15–15	1.84–15	9.12–16	3.34–16	7.76–17	1.13–17
$10p_{1/2}$	4.20–13	2.37–13	1.34–13	7.57–14	4.28–14	2.44–14	1.42–14	8.62–15	5.58–15	3.60–15	1.97–15	7.97–16	2.22–16	3.84–17	4.03–18
$10p_{3/2}$	1.21–12	6.81–13	3.85–13	2.17–13	1.23–13	6.97–14	4.00–14	2.35–14	1.41–14	8.13–15	3.93–15	1.42–15	3.54–16	5.49–17	5.02–18

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$10d_{3/2}$	1.16–12	6.53–13	3.69–13	2.09–13	1.19–13	6.95–14	4.23–14	2.68–14	1.63–14	8.15–15	2.98–15	7.80–16	1.46–16	1.78–17	1.28–18
$10d_{5/2}$	1.87–12	1.05–12	5.95–13	3.37–13	1.92–13	1.11–13	6.71–14	4.17–14	2.47–14	1.20–14	4.26–15	1.09–15	2.01–16	2.42–17	1.72–18
$10f_{5/2}$	2.92–12	1.65–12	9.31–13	5.27–13	3.00–13	1.73–13	1.01–13	5.53–14	2.52–14	8.62–15	2.20–15	4.40–16	6.97–17	7.76–18	5.26–19
$10f_{7/2}$	3.93–12	2.22–12	1.25–12	7.11–13	4.04–13	2.33–13	1.35–13	7.36–14	3.34–14	1.13–14	2.87–15	5.72–16	9.01–17	1.00–17	6.77–19
$10g_{7/2}$	5.08–12	2.87–12	1.62–12	9.11–13	5.06–13	2.73–13	1.35–13	5.55–14	1.77–14	4.37–15	8.88–16	1.57–16	2.35–17	2.56–18	1.72–19
$10g_{9/2}$	6.34–12	3.57–12	2.02–12	1.14–12	6.32–13	3.40–13	1.68–13	6.89–14	2.19–14	5.41–15	1.10–15	1.94–16	2.91–17	3.16–18	2.13–19
$10h_{9/2}$	4.55–12	2.57–12	1.45–12	8.09–13	4.38–13	2.19–13	9.30–14	3.06–14	7.77–15	1.62–15	3.02–16	5.15–17	7.60–18	8.23–19	5.53–20
$10h_{11/2}$	5.46–12	3.08–12	1.74–12	9.70–13	5.25–13	2.63–13	1.11–13	3.67–14	9.31–15	1.94–15	3.62–16	6.16–17	9.10–18	9.86–19	6.62–20
$10i_{11/2}$	3.53–12	1.99–12	1.12–12	6.22–13	3.28–13	1.54–13	5.81–14	1.66–14	3.71–15	7.21–16	1.30–16	2.19–17	3.22–18	3.48–19	2.33–20
$10i_{13/2}$	4.12–12	2.32–12	1.31–12	7.25–13	3.82–13	1.80–13	6.78–14	1.93–14	4.33–15	8.41–16	1.51–16	2.55–17	3.75–18	4.05–19	2.72–20
$11s_{1/2}$	3.50–13	1.98–13	1.12–13	6.32–14	3.57–14	2.03–14	1.15–14	6.58–15	3.82–15	2.30–15	1.34–15	6.62–16	2.42–16	5.62–17	8.20–18
$11p_{1/2}$	3.19–13	1.80–13	1.02–13	5.75–14	3.25–14	1.84–14	1.06–14	6.39–15	4.09–15	2.63–15	1.43–15	5.80–16	1.61–16	2.79–17	2.93–18
$11p_{3/2}$	9.11–13	5.14–13	2.91–13	1.64–13	9.28–14	5.25–14	3.00–14	1.74–14	1.04–14	5.96–15	2.88–15	1.04–15	2.59–16	4.01–17	3.67–18
$11d_{3/2}$	8.54–13	4.82–13	2.73–13	1.55–13	8.83–14	5.14–14	3.13–14	1.98–14	1.20–14	6.00–15	2.19–15	5.74–16	1.07–16	1.31–17	9.40–19
$11d_{5/2}$	1.38–12	7.79–13	4.41–13	2.50–13	1.43–13	8.27–14	4.97–14	3.08–14	1.82–14	8.83–15	3.14–15	8.05–16	1.48–16	1.79–17	1.27–18
$11f_{5/2}$	2.13–12	1.20–12	6.81–13	3.86–13	2.20–13	1.28–13	7.45–14	4.11–14	1.88–14	6.44–15	1.64–15	3.29–16	5.21–17	5.79–18	3.92–19
$11f_{7/2}$	2.87–12	1.62–12	9.19–13	5.21–13	2.97–13	1.72–13	1.00–13	5.48–14	2.49–14	8.47–15	2.15–15	4.28–16	6.75–17	7.50–18	5.07–19
$11g_{7/2}$	3.94–12	2.22–12	1.26–12	7.09–13	3.94–13	2.12–13	1.05–13	4.33–14	1.38–14	3.41–15	6.94–16	1.23–16	1.84–17	2.00–18	1.34–19
$11g_{9/2}$	4.92–12	2.78–12	1.57–12	8.85–13	4.92–13	2.65–13	1.31–13	5.39–14	1.72–14	4.23–15	8.59–16	1.52–16	2.27–17	2.47–18	1.66–19
$11h_{9/2}$	3.85–12	2.17–12	1.23–12	6.86–13	3.71–13	1.86–13	7.87–14	2.59–14	6.57–15	1.37–15	2.55–16	4.35–17	6.42–18	6.96–19	4.67–20
$11h_{11/2}$	4.61–12	2.60–12	1.47–12	8.22–13	4.45–13	2.23–13	9.44–14	3.11–14	7.87–15	1.64–15	3.06–16	5.21–17	7.68–18	8.33–19	5.59–20
$11i_{11/2}$	3.28–12	1.85–12	1.05–12	5.80–13	3.06–13	1.44–13	5.42–14	1.54–14	3.46–15	6.71–16	1.21–16	2.03–17	2.99–18	3.24–19	2.17–20
$11i_{13/2}$	3.83–12	2.16–12	1.22–12	6.77–13	3.57–13	1.67–13	6.32–14	1.80–14	4.03–15	7.82–16	1.41–16	2.37–17	3.49–18	3.77–19	2.53–20
$12s_{1/2}$	2.71–13	1.53–13	8.66–14	4.90–14	2.77–14	1.57–14	8.88–15	5.02–15	2.89–15	1.73–15	1.00–15	4.95–16	1.81–16	4.20–17	6.13–18
$12p_{1/2}$	2.49–13	1.40–13	7.95–14	4.50–14	2.54–14	1.43–14	8.21–15	4.88–15	3.10–15	1.98–15	1.08–15	4.36–16	1.21–16	2.10–17	2.20–18
$12p_{3/2}$	7.06–13	3.99–13	2.26–13	1.28–13	7.21–14	4.07–14	2.31–14	1.33–14	7.85–15	4.49–15	2.17–15	7.80–16	1.94–16	3.01–17	2.76–18
$12d_{3/2}$	6.51–13	3.68–13	2.09–13	1.18–13	6.75–14	3.92–14	2.38–14	1.50–14	9.11–15	4.55–15	1.66–15	4.35–16	8.15–17	9.95–18	7.09–19
$12d_{5/2}$	1.06–12	5.97–13	3.38–13	1.92–13	1.09–13	6.33–14	3.79–14	2.34–14	1.38–14	6.69–15	2.38–15	6.10–16	1.12–16	1.35–17	9.58–19
$12f_{5/2}$	1.60–12	9.07–13	5.14–13	2.92–13	1.67–13	9.68–14	5.67–14	3.14–14	1.44–14	4.94–15	1.26–15	2.53–16	4.00–17	4.47–18	3.01–19
$12f_{7/2}$	2.17–12	1.23–12	6.96–13	3.95–13	2.25–13	1.31–13	7.62–14	4.19–14	1.91–14	6.49–15	1.65–15	3.29–16	5.20–17	5.79–18	3.92–19
$12g_{7/2}$	3.10–12	1.75–12	9.94–13	5.60–13	3.12–13	1.68–13	8.32–14	3.43–14	1.10–14	2.71–15	5.51–16	9.92–17	1.46–17	1.59–18	1.07–19
$12g_{9/2}$	3.88–12	2.19–12	1.24–12	7.01–13	3.90–13	2.10–13	1.04–13	4.27–14	1.36–14	3.36–15	6.91–16	1.26–16	1.95–17	2.18–18	1.48–19
$12h_{9/2}$	3.23–12	1.83–12	1.03–12	5.78–13	3.13–13	1.56–13	6.63–14	2.18–14	5.52–15	1.15–15	2.14–16	3.65–17	5.39–18	5.84–19	3.92–20
$12h_{11/2}$	3.88–12	2.19–12	1.24–12	6.94–13	3.75–13	1.88–13	7.95–14	2.61–14	6.61–15	1.38–15	2.57–16	4.37–17	6.45–18	7.00–19	4.69–20
$12i_{11/2}$	2.95–12	1.67–12	9.43–13	5.23–13	2.76–13	1.29–13	4.88–14	1.39–14	3.11–15	6.04–16	1.09–16	1.83–17	2.69–18	2.91–19	1.95–20
$12i_{13/2}$	3.44–12	1.95–12	1.10–12	6.10–13	3.22–13	1.51–13	5.69–14	1.62–14	3.63–15	7.04–16	1.27–16	2.13–17	3.14–18	3.39–19	2.28–20
total	1.04–09	5.88–10	3.32–10	1.85–10	1.01–10	5.32–11	2.65–11	1.24–11	5.31–12	2.01–12	6.64–13	1.88–13	4.32–14	6.95–15	7.36–16
W^{38+}															
$4d_{3/2}$	7.32–11	4.12–11	2.32–11	1.30–11	7.33–12	4.12–12	2.30–12	1.27–12	6.56–13	2.91–13	1.00–13	2.57–14	4.78–15	5.84–16	4.18–17
$4d_{5/2}$	1.07–10	6.02–11	3.38–11	1.90–11	1.07–11	6.01–12	3.36–12	1.84–12	9.43–13	4.12–13	1.39–13	3.50–14	6.41–15	7.73–16	5.50–17
$4f_{5/2}$	7.68–11	4.32–11	2.43–11	1.36–11	7.64–12	4.23–12	2.27–12	1.12–12	4.69–13	1.54–13	3.88–14	7.76–15	1.23–15	1.37–16	9.28–18
$4f_{7/2}$	1.00–10	5.64–11	3.17–11	1.78–11	9.97–12	5.52–12	2.96–12	1.46–12	6.09–13	1.99–13	4.99–14	9.96–15	1.57–15	1.75–16	1.19–17
$5s_{1/2}$	8.24–12	4.63–12	2.61–12	1.47–12	8.26–13	4.67–13	2.66–13	1.54–13	9.21–14	5.58–14	3.21–14	1.58–14	5.77–15	1.34–15	1.96–16
$5p_{1/2}$	9.19–12	5.17–12	2.91–12	1.64–12	9.23–13	5.23–13	3.00–13	1.78–13	1.09–13	6.55–14	3.40–14	1.35–14	3.73–15	6.45–16	6.78–17
$5p_{3/2}$	2.32–11	1.30–11	7.34–12	4.13–12	2.33–12	1.31–12	7.47–13	4.31–13	2.50–13	1.38–13	6.46–14	2.30–14	5.72–15	8.88–16	8.14–17
$5d_{3/2}$	3.02–11	1.70–11	9.56–12	5.38–12	3.03–12	1.71–12	9.63–13	5.40–13	2.87–13	1.31–13	4.57–14	1.18–14	2.21–15	2.70–16	1.94–17
$5d_{5/2}$	4.51–11	2.54–11	1.43–11	8.04–12	4.52–12	2.55–12	1.43–12	7.99–13	4.20–13	1.87–13	6.43–14	1.63–14	3.00–15	3.62–16	2.58–17
$5f_{5/2}$	4.51–11	2.54–11	1.43–11	8.03–12	4.50–12	2.50–12	1.35–12	6.77–13	2.89–13	9.66–14	2.46–14	4.96–15	7.88–16	8.79–17	5.96–18
$5f_{7/2}$	5.94–11	3.34–11	1.88–11	1.06–11	5.92–12	3.29–12	1.77–12	8.89–13	3.79–13	1.26–13	3.19–14	6.40–15	1.01–15	1.13–16	7.65–18
$5g_{7/2}$	2.16–11	1.21–11	6.83–12	3.83–12	2.13–12	1.15–12	5.81–13	2.52–13	8.57–14	2.23–14	4.70–15	8.46–16	1.27–16	1.39–17	9.35–19
$5g_{9/2}$	2.67–11	1.50–11	8.46–12	4.75–12	2.64–12	1.43–12	7.19–13	3.11–13	1.06–13	2.76–14	5.80–15	1.04–15	1.57–16	1.71–17	1.15–18
$6s_{1/2}$	4.52–12	2.54–12	1.43–12	8.06–13	4.54–13	2.57–13	1.46–13	8.46–14	5.01–14	2.99–14	1.70–14	8.32–15	3.03–15	7.02–16	1.02–16
$6p_{1/2}$	4.82–12	2.71–12	1.53–12	8.61–13	4.86–13	2.75–13	1.59–13	9.42–14	5.79–14	3.49–14	1.81–14	7.18–15	1.99–15	3.43–16	3.60–17
$6p_{3/2}$	1.26–11	7.12–12	4.01–12	2.25–12	1.27–12	7.18–13	4.09–13	2.36–13	1.37–13	7.50–14	3.50–14	1.25–14	3.09–15	4.80–16	4.39–17
$6d_{3/2}$	1.61–11	9.09–12	5.11–12	2.88–12	1.62–12	9.16–13	5.20–13	2.94–13	1.58–13	7.26–14	2.56–14	6.64–15	1.24–15	1.52–16	1.09–17
$6d_{5/2}$	2.44–11	1.37–11	7.72–12	4.34–12	2.45–12	1.38–12	7.81–13	4.39–13	2.33–13	1.05–13	3.61–14	9.19–15	1.69–15	2.04–16	1.45–17
$6f_{5/2}$	2.78–11	1.57–11	8.82–12	4.96–12	2.78–12	1.55–12	8.41–13	4.26–13	1.84–13	6.19–14	1.59–14	3.20–15	5.09–16	5.68–17	3.85–18
$6f_{7/2}$	3.68–11	2.07–11	1.17–11	6.55–12	3.67–12	2.04–12	1.11–12	5.60–13	2.41–13	8.06–14	2.06–14	4.13–15	6.56–16	7.31–17	4.95–18
$6g_{7/2}$	2.21–11	1.24–11	7.00–12	3.93–12	2.18–12	1.18–12	5.98–13	2.60–13	8.88–14	2.32–14	4.90–15	8.83–16	1.33–16	1.45–17	9.77–19
$6g_{9/2}$	2.74–11	1.54–11	8.68–12	4.87–12	2.71–12	1.47–12	7.41–13	3.22–13	1.10–13	2.87–14	6.05–15	1.09–15	1.64–16	1.79–17	1.20–18
$6h_{9/2}$	7.73–12	4.35–12	2.45–12	1.37–12	7.51–13	3.94–13	1.84–13	6.94–14	1.99–14	4.49–15	8.66–16	1.50–16	2.22–17	2.41–18	1.62–19
$6h_{11/2}$	9.24–12	5.20–12	2.92–12	1.64–12	8.99–13	4.71–13	2.20–13	8.29–14	2.38–14	5.36–15	1.03–15	1.79–16	2.65–17	2.87–18	1.93–19
$7s_{1/2}$	2.81–12	1.58–12	8.89–13	5.01–13	2.82–13	1.60–13	9.08–14	5.24–14	3.06–14	1.80–14	1.02–14	4.93–15	1.79–15	4.14–16	6.03–17
$7p_{1/2}$	2.91–12	1.64–12	9.23–13	5.20–13	2.93–13	1.67–13	9.61–14	5.71–14	3.49–14	2.09–14	1.08–14	4.29–15	1.18–15	2.04–16	2.15–17
$7p_{3/2}$	7.81–12	4.39–12	2.47–12	1.39–12	7.85–13	4.44–13	2.52–13	1.45–13	8.36–14	4.56–14	2.12–14	7.51–15	1.86–15	2.89–16	2.64–17

(continued on next page)

Table 1 (*continued*)

Shell	$\log_{10} T\,(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$7d_{3/2}$	9.74–12	5.48–12	3.09–12	1.74–12	9.80–13	5.55–13	3.16–13	1.80–13	9.71–14	4.47–14	1.58–14	4.09–15	7.66–16	9.38–17	6.73–18
$7d_{5/2}$	1.48–11	8.33–12	4.69–12	2.64–12	1.49–12	8.42–13	4.78–13	2.70–13	1.44–13	6.47–14	2.23–14	5.68–15	1.05–15	1.26–16	9.00–18
$7f_{5/2}$	1.81–11	1.02–11	5.72–12	3.22–12	1.81–12	1.01–12	5.50–13	2.80–13	1.22–13	4.11–14	1.06–14	2.13–15	3.39–16	3.79–17	2.57–18
$7f_{7/2}$	2.39–11	1.35–11	7.58–12	4.27–12	2.39–12	1.33–12	7.27–13	3.69–13	1.60–13	5.36–14	1.37–14	2.76–15	4.38–16	4.88–17	3.30–18
$7g_{7/2}$	1.81–11	1.02–11	5.75–12	3.22–12	1.79–12	9.72–13	4.93–13	2.15–13	7.35–14	1.93–14	4.07–15	7.33–16	1.10–16	1.21–17	8.11–19
$7g_{9/2}$	2.25–11	1.27–11	7.13–12	4.00–12	2.23–12	1.21–12	6.11–13	2.66–13	9.10–14	2.38–14	5.02–15	9.04–16	1.36–16	1.49–17	1.00–18
$7h_{9/2}$	1.07–11	6.02–12	3.39–12	1.89–12	1.04–12	5.46–13	2.55–13	9.62–14	2.76–14	6.23–15	1.20–15	2.07–16	3.08–17	3.34–18	2.24–19
$7h_{11/2}$	1.28–11	7.20–12	4.05–12	2.27–12	1.24–12	6.53–13	3.05–13	1.15–13	3.30–14	7.43–15	1.43–15	2.48–16	3.67–17	3.98–18	2.67–19
$7i_{11/2}$	3.51–12	1.98–12	1.11–12	6.19–13	3.35–13	1.69–13	7.27–14	2.41–14	6.08–15	1.26–15	2.32–16	3.94–17	5.81–18	6.30–19	4.23–20
$7i_{13/2}$	4.09–12	2.30–12	1.29–12	7.21–13	3.91–13	1.97–13	8.46–14	2.81–14	7.07–15	1.46–15	2.70–16	4.59–17	6.76–18	7.33–19	4.92–20
$8s_{1/2}$	1.88–12	1.06–12	5.97–13	3.36–13	1.90–13	1.07–13	6.09–14	3.49–14	2.02–14	1.17–14	6.54–15	3.16–15	1.15–15	2.65–16	3.85–17
$8p_{1/2}$	1.92–12	1.08–12	6.09–13	3.43–13	1.94–13	1.10–13	6.34–14	3.75–14	2.28–14	1.36–14	6.99–15	2.76–15	7.62–16	1.32–16	1.38–17
$8p_{3/2}$	5.22–12	2.94–12	1.66–12	9.32–13	5.25–13	2.97–13	1.69–13	9.65–14	5.51–14	2.98–14	1.38–14	4.88–15	1.21–15	1.87–16	1.71–17
$8d_{3/2}$	6.37–12	3.59–12	2.02–12	1.14–12	6.43–13	3.64–13	2.08–13	1.18–13	6.41–14	2.95–14	1.04–14	2.70–15	5.06–16	6.19–17	4.45–18
$8d_{5/2}$	9.74–12	5.48–12	3.09–12	1.74–12	9.82–13	5.55–13	3.16–13	1.78–13	9.50–14	4.28–14	1.48–14	3.76–15	6.91–16	8.36–17	5.95–18
$8f_{5/2}$	1.23–11	6.93–12	3.91–12	2.20–12	1.23–12	6.89–13	3.77–13	1.93–13	8.39–14	2.84–14	7.31–15	1.48–15	2.35–16	2.62–17	1.78–18
$8f_{7/2}$	1.63–11	9.20–12	5.18–12	2.92–12	1.64–12	9.14–13	4.99–13	2.55–13	1.10–13	3.71–14	9.49–15	1.91–15	3.03–16	3.38–17	2.29–18
$8g_{7/2}$	1.41–11	7.96–12	4.49–12	2.52–12	1.40–12	7.60–13	3.86–13	1.68–13	5.77–14	1.51–14	3.19–15	5.75–16	8.67–17	9.47–18	6.37–19
$8g_{9/2}$	1.76–11	9.90–12	5.58–12	3.13–12	1.74–12	9.45–13	4.79–13	2.09–13	7.15–14	1.87–14	3.95–15	7.11–16	1.07–16	1.17–17	7.86–19
$8h_{9/2}$	1.07–11	6.02–12	3.39–12	1.90–12	1.04–12	5.47–13	2.56–13	9.64–14	2.76–14	6.24–15	1.20–15	2.08–16	3.08–17	3.34–18	2.24–19
$8h_{11/2}$	1.28–11	7.21–12	4.05–12	2.27–12	1.25–12	6.54–13	3.06–13	1.15–13	3.30–14	7.45–15	1.44–15	2.48–16	3.68–17	3.99–18	2.68–19
$8i_{11/2}$	5.83–12	3.28–12	1.84–12	1.03–12	5.57–13	2.81–13	1.21–13	4.01–14	1.01–14	2.09–15	3.85–16	6.55–17	9.65–18	1.05–18	7.01–20
$8i_{13/2}$	6.78–12	3.82–12	2.15–12	1.20–12	6.49–13	3.27–13	1.41–13	4.66–14	1.17–14	2.43–15	4.48–16	7.62–17	1.12–17	1.22–18	8.16–20
$9s_{1/2}$	1.34–12	7.52–13	4.24–13	2.39–13	1.35–13	7.60–14	4.31–14	2.45–14	1.40–14	8.04–15	4.46–15	2.15–15	7.77–16	1.80–16	2.61–17
$9p_{1/2}$	1.35–12	7.58–13	4.27–13	2.41–13	1.36–13	7.71–14	4.44–14	2.61–14	1.58–14	9.29–15	4.78–15	1.88–15	5.20–16	8.98–17	9.42–18
$9p_{3/2}$	3.69–12	2.08–12	1.17–12	6.61–13	3.72–13	2.10–13	1.19–13	6.77–14	3.83–14	2.06–14	9.47–15	3.34–15	8.28–16	1.28–16	1.17–17
$9d_{3/2}$	4.43–12	2.49–12	1.41–12	7.92–13	4.47–13	2.53–13	1.45–13	8.25–14	4.45–14	2.05–14	7.22–15	1.87–15	3.51–16	4.30–17	3.08–18
$9d_{5/2}$	6.80–12	3.83–12	2.16–12	1.22–12	6.86–13	3.88–13	2.21–13	1.25–13	6.62–14	2.98–14	1.03–14	2.61–15	4.80–16	5.81–17	4.13–18
$9f_{5/2}$	8.76–12	4.93–12	2.78–12	1.57–12	8.80–13	4.92–13	2.69–13	1.38–13	6.01–14	2.04–14	5.24–15	1.06–15	1.69–16	1.89–17	1.28–18
$9f_{7/2}$	1.16–11	6.56–12	3.70–12	2.08–12	1.17–12	6.53–13	3.58–13	1.82–13	7.91–14	2.66–14	6.81–15	1.37–15	2.18–16	2.43–17	1.64–18
$9g_{7/2}$	1.10–11	6.18–12	3.48–12	1.96–12	1.09–12	5.91–13	3.00–13	1.31–13	4.49–14	1.18–14	2.48–15	4.48–16	6.75–17	7.36–18	4.95–19
$9g_{9/2}$	1.37–11	7.69–12	4.34–12	2.43–12	1.35–12	7.35–13	3.73–13	1.63–13	5.56–14	1.46–14	3.07–15	5.53–16	8.34–17	9.10–18	6.12–19
$9h_{9/2}$	9.60–12	5.40–12	3.04–12	1.70–12	9.37–13	4.91–13	2.30–13	8.66–14	2.48–14	5.60–15	1.08–15	1.86–16	2.76–17	3.00–18	2.01–19
$9h_{11/2}$	1.15–11	6.47–12	3.64–12	2.04–12	1.12–12	5.88–13	2.75–13	1.04–13	2.97–14	6.68–15	1.29–15	2.22–16	3.30–17	3.58–18	2.40–19
$9i_{11/2}$	6.67–12	3.76–12	2.11–12	1.18–12	6.39–13	3.22–13	1.38–13	4.59–14	1.16–14	2.39–15	4.41–16	7.49–17	1.10–17	1.20–18	8.03–20
$9i_{13/2}$	7.77–12	4.37–12	2.46–12	1.37–12	7.44–13	3.75–13	1.61–13	5.35–14	1.35–14	2.78–15	5.13–16	8.72–17	1.29–17	1.39–18	9.34–20
$10s_{1/2}$	9.86–13	5.55–13	3.13–13	1.77–13	9.95–14	5.62–14	3.18–14	1.80–14	1.01–14	5.76–15	3.18–15	1.53–15	5.51–16	1.27–16	1.85–17
$10p_{1/2}$	9.88–13	5.56–13	3.14–13	1.77–13	9.99–14	5.66–14	3.25–14	1.90–14	1.14–14	6.65–15	3.41–15	1.34–15	3.70–16	6.38–17	6.70–18
$10p_{3/2}$	2.73–12	1.54–12	8.66–13	4.88–13	2.75–13	1.55–13	8.76–14	4.95–14	2.77–14	1.48–14	6.79–15	2.39–15	5.92–16	9.16–17	8.38–18
$10d_{3/2}$	3.22–12	1.81–12	1.02–12	5.76–13	3.25–13	1.84–13	1.05–13	5.99–14	3.23–14	1.48–14	5.21–15	1.35–15	2.53–16	3.10–17	2.22–18
$10d_{5/2}$	4.96–12	2.79–12	1.57–12	8.88–13	5.01–13	2.83–13	1.61–13	9.07–14	4.80–14	2.16–14	7.42–15	1.89–15	3.47–16	4.20–17	2.99–18
$10f_{5/2}$	6.46–12	3.64–12	2.05–12	1.16–12	6.50–13	3.63–13	1.99–13	1.02–13	4.45–14	1.51–14	3.88–15	7.84–16	1.25–16	1.39–17	9.45–19
$10f_{7/2}$	8.60–12	4.85–12	2.73–12	1.54–12	8.66–13	4.84–13	2.65–13	1.35–13	5.86–14	1.97–14	5.04–15	1.02–15	1.61–16	1.80–17	1.22–18
$10g_{7/2}$	8.58–12	4.84–12	2.73–12	1.53–12	8.53–13	4.63–13	2.35–13	1.03–13	3.51–14	9.20–15	1.94–15	3.50–16	5.28–17	5.76–18	3.88–19
$10g_{9/2}$	1.07–11	6.02–12	3.40–12	1.91–12	1.06–12	5.76–13	2.93–13	1.27–13	4.36–14	1.14–14	2.40–15	4.33–16	6.52–17	7.12–18	4.79–19
$10h_{9/2}$	8.25–12	4.65–12	2.62–12	1.47–12	8.06–13	4.23–13	1.98–13	7.45–14	2.13–14	4.80–15	9.26–16	1.60–16	2.37–17	2.57–18	1.73–19
$10h_{11/2}$	9.87–12	5.56–12	3.13–12	1.76–12	9.66–13	5.06–13	2.37–13	8.91–14	2.55–14	5.74–15	1.11–15	1.91–16	2.83–17	3.07–18	2.06–19
$10i_{11/2}$	6.63–12	3.73–12	2.10–12	1.17–12	6.35–13	3.21–13	1.38–13	4.56–14	1.15–14	2.37–15	4.38–16	7.44–17	1.10–17	1.19–18	7.98–20
$10i_{13/2}$	7.72–12	4.35–12	2.45–12	1.37–12	7.40–13	3.73–13	1.60–13	5.32–14	1.34–14	2.76–15	5.10–16	8.66–17	1.28–17	1.38–18	9.28–20
$11s_{1/2}$	7.52–13	4.24–13	2.39–13	1.35–13	7.60–14	4.28–14	2.41–14	1.35–14	7.58–15	4.27–15	2.34–15	1.12–15	4.05–16	9.35–17	1.36–17
$11p_{1/2}$	7.50–13	4.23–13	2.39–13	1.35–13	7.60–14	4.30–14	2.46–14	1.43–14	8.46–15	4.93–15	2.52–15	9.90–16	2.73–16	4.70–17	4.92–18
$11p_{3/2}$	2.08–12	1.17–12	6.61–13	3.73–13	2.10–13	1.18–13	6.65–14	3.73–14	2.08–14	1.10–14	5.03–15	1.77–15	4.38–16	6.77–17	6.20–18
$11d_{3/2}$	2.42–12	1.36–12	7.69–13	4.34–13	2.45–13	1.39–13	7.92–14	4.49–14	2.41–14	1.10–14	3.88–15	1.01–15	1.89–16	2.31–17	1.65–18
$11d_{5/2}$	3.74–12	2.11–12	1.19–12	6.71–13	3.79–13	2.14–13	1.21–13	6.82–14	3.60–14	1.61–14	5.54–15	1.41–15	2.59–16	3.13–17	2.23–18
$11f_{5/2}$	4.90–12	2.76–12	1.56–12	8.79–13	4.95–13	2.77–13	1.52–13	7.76–14	3.38–14	1.14–14	2.94–15	5.97–16	9.54–17	1.07–17	7.28–19
$11f_{7/2}$	6.54–12	3.69–12	2.08–12	1.17–12	6.60–13	3.69–13	2.02–13	1.03–13	4.45–14	1.50–14	3.83–15	7.71–16	1.22–16	1.36–17	9.21–19
$11g_{7/2}$	6.80–12	3.83–12	2.16–12	1.22–12	6.77–13	3.67–13	1.86–13	8.13–14	2.78–14	7.28–15	1.54–15	2.77–16	4.17–17	4.55–18	3.06–19
$11g_{9/2}$	8.47–12	4.77–12	2.69–12	1.51–12	8.43–13	4.58–13	2.32–13	1.01–13	3.45–14	9.01–15	1.90–15	3.42–16	5.16–17	5.63–18	3.79–19
$11h_{9/2}$	6.97–12	3.93–12	2.22–12	1.24–12	6.83–13	3.58–13	1.67–13	6.30–14	1.80–14	4.05–15	7.81–16	1.35–16	2.00–17	2.17–18	1.46–19
$11h_{11/2}$	8.35–12	4.71–12	2.65–12	1.49–12	8.18–13	4.29–13	2.00–13	7.53–14	2.15–14	4.84–15	9.33–16	1.61–16	2.39–17	2.59–18	1.74–19
$11i_{11/2}$	6.17–12	3.48–12	1.96–12	1.09–12	5.92–13	2.99–13	1.28–13	4.25–14	1.07–14	2.21–15	4.07–16	6.92–17	1.02–17	1.10–18	7.41–20
$11i_{13/2}$	7.19–12	4.05–12	2.28–12	1.27–12	6.90–13	3.48–13	1.49–13	4.95–14	1.24–14	2.57–15	4.74–16	8.05–17	1.19–17	1.29–18	8.63–20
$12s_{1/2}$	5.89–13	3.32–13	1.87–13	1.06–13	5.95–14	3.35–14	1.88–14	1.05–14	5.81–15	3.25–15	1.77–15	8.49–16	3.06–16	7.06–17	1.03–17
$12p_{1/2}$	5.86–13	3.31–13	1.87–13	1.05–13	5.94–14	3.36–14	1.91–14	1.10–14	6.47–15	3.75–15	1.91–15	7.52–16	2.07–16	3.57–17	3.73–18
$12p_{3/2}$	1.63–12	9.18–13	5.19–13	2.93–13	1.65–13	9.25–14	5.18–14	2.89–14	1.59–14	8.39–15	3.82–15	1.35–15	3.32–16	5.14–17	4.70–18

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$12d_{3/2}$	1.87–12	1.06–12	5.96–13	3.37–13	1.90–13	1.08–13	6.12–14	3.46–14	1.85–14	8.45–15	2.97–15	7.70–16	1.44–16	1.76–17	1.26–18
$12d_{5/2}$	2.90–12	1.64–12	9.24–13	5.22–13	2.94–13	1.66–13	9.40–14	5.26–14	2.76–14	1.23–14	4.24–15	1.08–15	1.98–16	2.40–17	1.70–18
$12f_{5/2}$	3.82–12	2.15–12	1.22–12	6.86–13	3.86–13	2.16–13	1.18–13	6.04–14	2.62–14	8.87–15	2.28–15	4.61–16	7.35–17	8.20–18	5.56–19
$12f_{7/2}$	5.10–12	2.87–12	1.62–12	9.16–13	5.15–13	2.88–13	1.57–13	8.01–14	3.46–14	1.16–14	2.97–15	5.99–16	9.52–17	1.06–17	7.18–19
$12g_{7/2}$	5.46–12	3.08–12	1.74–12	9.78–13	5.44–13	2.95–13	1.50–13	6.52–14	2.23–14	5.82–15	1.23–15	2.24–16	3.38–17	3.70–18	2.49–19
$12g_{9/2}$	6.81–12	3.84–12	2.17–12	1.22–12	6.78–13	3.68–13	1.86–13	8.10–14	2.76–14	7.22–15	1.52–15	2.74–16	4.14–17	4.52–18	3.04–19
$12h_{9/2}$	5.87–12	3.31–12	1.87–12	1.05–12	5.76–13	3.02–13	1.41–13	5.29–14	1.51–14	3.40–15	6.55–16	1.13–16	1.68–17	1.82–18	1.22–19
$12h_{11/2}$	7.03–12	3.97–12	2.24–12	1.25–12	6.90–13	3.62–13	1.69–13	6.33–14	1.81–14	4.07–15	7.83–16	1.35–16	2.00–17	2.18–18	1.46–19
$12i_{11/2}$	5.55–12	3.13–12	1.77–12	9.85–13	5.34–13	2.69–13	1.15–13	3.82–14	9.61–15	1.98–15	3.66–16	6.22–17	9.16–18	9.93–19	6.66–20
$12i_{13/2}$	6.47–12	3.65–12	2.06–12	1.15–12	6.22–13	3.14–13	1.35–13	4.45–14	1.12–14	2.31–15	4.26–16	7.24–17	1.07–17	1.16–18	7.76–20
total	1.89–09	1.06–09	5.99–10	3.35–10	1.85–10	9.87–11	5.00–11	2.35–11	1.01–11	3.85–12	1.27–12	3.49–13	7.68–14	1.18–14	1.20–15
$\boldsymbol{W^{46+}}$															
$4s_{1/2}$	2.38–11	1.34–11	7.51–12	4.23–12	2.38–12	1.34–12	7.58–13	4.34–13	2.53–13	1.49–13	8.50–14	4.17–14	1.52–14	3.55–15	5.20–16
$4p_{1/2}$	3.00–11	1.69–11	9.49–12	5.34–12	3.00–12	1.69–12	9.59–13	5.50–13	3.19–13	1.82–13	9.13–14	3.58–14	9.87–15	1.71–15	1.80–16
$4p_{3/2}$	6.75–11	3.80–11	2.14–11	1.20–11	6.76–12	3.80–12	2.14–12	1.21–12	6.80–13	3.63–13	1.67–13	5.94–14	1.48–14	2.30–15	2.12–16
$4d_{3/2}$	8.06–11	4.53–11	2.55–11	1.43–11	8.05–12	4.52–12	2.52–12	1.37–12	7.04–13	3.11–13	1.08–13	2.79–14	5.24–15	6.43–16	4.62–17
$4d_{5/2}$	1.17–10	6.58–11	3.70–11	2.08–11	1.17–11	6.55–12	3.65–12	1.98–12	1.01–12	4.40–13	1.50–13	3.81–14	7.02–15	8.51–16	6.07–17
$4f_{5/2}$	6.64–11	3.74–11	2.10–11	1.18–11	6.61–12	3.67–12	1.98–12	9.94–13	4.29–13	1.46–13	3.80–14	7.77–15	1.24–15	1.39–16	9.44–18
$4f_{7/2}$	8.65–11	4.86–11	2.74–11	1.54–11	8.61–12	4.77–12	2.58–12	1.29–12	5.55–13	1.88–13	4.88–14	9.94–15	1.59–15	1.77–16	1.20–17
$5s_{1/2}$	1.16–11	6.54–12	3.68–12	2.07–12	1.17–12	6.57–13	3.72–13	2.13–13	1.24–13	7.22–14	4.05–14	1.96–14	7.13–15	1.65–15	2.41–16
$5p_{1/2}$	1.38–11	7.79–12	4.38–12	2.47–12	1.39–12	7.84–13	4.45–13	2.57–13	1.50–13	8.60–14	4.33–14	1.70–14	4.67–15	8.08–16	8.51–17
$5p_{3/2}$	3.31–11	1.86–11	1.05–11	5.89–12	3.31–12	1.87–12	1.05–12	5.96–13	3.35–13	1.78–13	8.17–14	2.89–14	7.19–15	1.12–15	1.03–16
$5d_{3/2}$	4.08–11	2.29–11	1.29–11	7.26–12	4.08–12	2.29–12	1.28–12	7.04–13	3.64–13	1.62–13	5.66–14	1.47–14	2.76–15	3.39–16	2.44–17
$5d_{5/2}$	6.00–11	3.37–11	1.90–11	1.07–11	6.00–12	3.37–12	1.88–12	1.03–12	5.27–13	2.31–13	7.92–14	2.02–14	3.73–15	4.52–16	3.22–17
$5f_{5/2}$	4.99–11	2.81–11	1.58–11	8.88–12	4.97–12	2.76–12	1.49–12	7.53–13	3.26–13	1.11–13	2.91–14	5.97–15	9.56–16	1.07–16	7.26–18
$5f_{7/2}$	6.53–11	3.67–11	2.07–11	1.16–11	6.51–12	3.61–12	1.95–12	9.83–13	4.24–13	1.44–13	3.75–14	7.65–15	1.22–15	1.37–16	9.27–18
$5g_{7/2}$	2.23–11	1.25–11	7.05–12	3.95–12	2.20–12	1.20–12	6.19–13	2.79–13	1.00–13	2.75–14	5.99–15	1.10–15	1.66–16	1.82–17	1.22–18
$5g_{9/2}$	2.76–11	1.55–11	8.74–12	4.90–12	2.73–12	1.49–12	7.66–13	3.45–13	1.24–13	3.39–14	7.38–15	1.35–15	2.05–16	2.24–17	1.51–18
$6s_{1/2}$	6.70–12	3.77–12	2.12–12	1.19–12	6.72–13	3.79–13	2.15–13	1.23–13	7.08–14	4.07–14	2.25–14	1.08–14	3.90–15	9.03–16	1.32–16
$6p_{1/2}$	7.68–12	4.32–12	2.43–12	1.37–12	7.71–13	4.36–13	2.48–13	1.44–13	8.42–14	4.80–14	2.41–14	9.40–15	2.59–15	4.47–16	4.70–17
$6p_{3/2}$	1.90–11	1.07–11	6.03–12	3.39–12	1.91–12	1.08–12	6.07–13	3.44–13	1.92–13	1.02–13	4.62–14	1.63–14	4.04–15	6.26–16	5.75–17
$6d_{3/2}$	2.35–11	1.32–11	7.45–12	4.19–12	2.36–12	1.33–12	7.43–13	4.10–13	2.13–13	9.50–14	3.32–14	8.62–15	1.62–15	1.99–16	1.43–17
$6d_{5/2}$	3.49–11	1.97–11	1.11–11	6.22–12	3.50–12	1.96–12	1.10–12	6.04–13	3.10–13	1.36–13	4.66–14	1.19–14	2.19–15	2.66–16	1.90–17
$6f_{5/2}$	3.41–11	1.92–11	1.08–11	6.06–12	3.40–12	1.89–12	1.02–12	5.17–13	2.25–13	7.68–14	2.01–14	4.11–15	6.59–16	7.38–17	5.01–18
$6f_{7/2}$	4.47–11	2.52–11	1.42–11	7.96–12	4.46–12	2.48–12	1.34–12	6.77–13	2.93–13	9.96–14	2.59–14	5.29–15	8.45–16	9.45–17	6.41–18
$6g_{7/2}$	2.50–11	1.41–11	7.91–12	4.44–12	2.47–12	1.35–12	6.95–13	3.14–13	1.13–13	3.09–14	6.73–15	1.23–15	1.87–16	2.04–17	1.38–18
$6g_{9/2}$	3.10–11	1.74–11	9.81–12	5.51–12	3.07–12	1.67–12	8.62–13	3.89–13	1.39–13	3.82–14	8.31–15	1.52–15	2.30–16	2.52–17	1.70–18
$6h_{9/2}$	1.02–11	5.72–12	3.21–12	1.80–12	9.96–13	5.32–13	2.59–13	1.04–13	3.22–14	7.63–15	1.51–15	2.64–16	3.92–17	4.26–18	2.86–19
$6h_{11/2}$	1.21–11	6.83–12	3.84–12	2.15–12	1.19–12	6.34–13	3.09–13	1.25–13	3.83–14	9.09–15	1.80–15	3.14–16	4.67–17	5.08–18	3.41–19
$7s_{1/2}$	4.27–12	2.40–12	1.35–12	7.62–13	4.29–13	2.42–13	1.37–13	7.80–14	4.46–14	2.53–14	1.38–14	6.58–15	2.37–15	5.47–16	7.95–17
$7p_{1/2}$	4.77–12	2.68–12	1.51–12	8.51–13	4.79–13	2.71–13	1.54–13	8.93–14	5.23–14	2.96–14	1.48–14	5.75–15	1.58–15	2.73–16	2.86–17
$7p_{3/2}$	1.21–11	6.82–12	3.84–12	2.16–12	1.22–12	6.85–13	3.86–13	2.18–13	1.21–13	6.35–14	2.87–14	1.01–14	2.49–15	3.85–16	3.54–17
$7d_{3/2}$	1.49–11	8.37–12	4.71–12	2.65–12	1.49–12	8.40–13	4.71–13	2.61–13	1.35–13	6.04–14	2.10–14	5.47–15	1.03–15	1.26–16	9.07–18
$7d_{5/2}$	2.22–11	1.25–11	7.04–12	3.96–12	2.23–12	1.25–12	7.01–13	3.86–13	1.98–13	8.69–14	2.97–14	7.56–15	1.39–15	1.69–16	1.21–17
$7f_{5/2}$	2.35–11	1.32–11	7.45–12	4.19–12	2.35–12	1.31–12	7.09–13	3.59–13	1.56–13	5.33–14	1.39–14	2.85–15	4.57–16	5.12–17	3.47–18
$7f_{7/2}$	3.10–11	1.74–11	9.82–12	5.52–12	3.09–12	1.72–12	9.32–13	4.71–13	2.04–13	6.93–14	1.80–14	3.67–15	5.87–16	6.56–17	4.45–18
$7g_{7/2}$	2.17–11	1.22–11	6.87–12	3.86–12	2.15–12	1.17–12	6.05–13	2.73–13	9.79–14	2.68–14	5.84–15	1.07–15	1.62–16	1.77–17	1.19–18
$7g_{9/2}$	2.70–11	1.52–11	8.53–12	4.79–12	2.67–12	1.46–12	7.50–13	3.38–13	1.21–13	3.32–14	7.21–15	1.32–15	2.00–16	2.19–17	1.47–18
$7h_{9/2}$	1.41–11	7.96–12	4.48–12	2.51–12	1.39–12	7.41–13	3.61–13	1.46–13	4.48–14	1.06–14	2.10–15	3.67–16	5.46–17	5.94–18	3.99–19
$7h_{11/2}$	1.69–11	9.52–12	5.35–12	3.00–12	1.66–12	8.85–13	4.31–13	1.74–13	5.35–14	1.27–14	2.51–15	4.38–16	6.51–17	7.08–18	4.75–19
$7i_{11/2}$	5.09–12	2.86–12	1.61–12	8.99–13	4.93–13	2.56–13	1.17–13	4.25–14	1.16–14	2.52–15	4.74–16	8.12–17	1.20–17	1.30–18	8.73–20
$7i_{13/2}$	5.91–12	3.33–12	1.87–12	1.04–12	5.72–13	2.98–13	1.36–13	4.94–14	1.35–14	2.92–15	5.51–16	9.43–17	1.39–17	1.51–18	1.01–19
$8s_{1/2}$	2.91–12	1.64–12	9.23–13	5.20–13	2.93–13	1.65–13	9.33–14	5.29–14	3.00–14	1.68–14	9.08–15	4.30–15	1.54–15	3.56–16	5.17–17
$8p_{1/2}$	3.20–12	1.80–12	1.01–12	5.70–13	3.21–13	1.82–13	1.04–13	5.98–14	3.48–14	1.96–14	9.71–15	3.77–15	1.03–15	1.78–16	1.88–17
$8p_{3/2}$	8.26–12	4.65–12	2.62–12	1.47–12	8.30–13	4.67–13	2.63–13	1.48–13	8.17–14	4.24–14	1.90–14	6.65–15	1.64–15	2.54–16	2.33–17
$8d_{3/2}$	1.01–11	5.66–12	3.19–12	1.80–12	1.01–12	5.69–13	3.19–13	1.76–13	9.16–14	4.07–14	1.42–14	3.68–15	6.90–16	8.47–17	6.10–18
$8d_{5/2}$	1.51–11	8.50–12	4.79–12	2.69–12	1.51–12	8.51–13	4.77–13	2.62–13	1.34–13	5.88–14	2.00–14	5.09–15	9.39–16	1.14–16	8.12–18
$8f_{5/2}$	1.68–11	9.44–12	5.31–12	2.99–12	1.68–12	9.32–13	5.06–13	2.56–13	1.11–13	3.80–14	9.91–15	2.03–15	3.25–16	3.64–17	2.47–18
$8f_{7/2}$	2.21–11	1.25–11	7.02–12	3.94–12	2.21–12	1.23–12	6.67–13	3.37–13	1.46–13	4.94–14	1.28–14	2.62–15	4.18–16	4.67–17	3.17–18
$8g_{7/2}$	1.76–11	9.91–12	5.58–12	3.13–12	1.75–12	9.53–13	4.91–13	2.21–13	7.94–14	2.17–14	4.72–15	8.63–16	1.31–16	1.43–17	9.64–19
$8g_{9/2}$	2.19–11	1.23–11	6.93–12	3.89–12	2.17–12	1.18–12	6.10–13	2.75–13	9.83–14	2.69–14	5.83–15	1.07–15	1.62–16	1.77–17	1.19–18
$8h_{9/2}$	1.43–11	8.04–12	4.53–12	2.54–12	1.40–12	7.49–13	3.65–13	1.47–13	4.52–14	1.07–14	2.12–15	3.70–16	5.51–17	5.99–18	4.02–19
$8h_{11/2}$	1.71–11	9.62–12	5.41–12	3.03–12	1.68–12	8.95–13	4.36–13	1.76–13	5.40–14	1.28–14	2.53–15	4.41–16	6.57–17	7.14–18	4.80–19
$8i_{11/2}$	8.42–12	4.74–12	2.66–12	1.49–12	8.16–13	4.24–13	1.94–13	7.04–14	1.92–14	4.16–15	7.85–16	1.34–16	1.99–17	2.15–18	1.45–19
$8i_{13/2}$	9.79–12	5.51–12	3.10–12	1.73–12	9.49–13	4.93–13	2.26–13	8.19–14	2.23–14	4.84–15	9.12–16	1.56–16	2.31–17	2.50–18	1.68–19

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T\,(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$9s_{1/2}$	2.09–12	1.18–12	6.63–13	3.73–13	2.10–13	1.18–13	6.69–14	3.77–14	2.12–14	1.17–14	6.28–15	2.96–15	1.06–15	2.44–16	3.55–17
$9p_{1/2}$	2.26–12	1.27–12	7.18–13	4.04–13	2.28–13	1.29–13	7.33–14	4.22–14	2.44–14	1.36–14	6.72–15	2.60–15	7.14–16	1.23–16	1.29–17
$9p_{3/2}$	5.93–12	3.34–12	1.88–12	1.06–12	5.96–13	3.35–13	1.88–13	1.05–13	5.77–14	2.97–14	1.33–14	4.62–15	1.14–15	1.76–16	1.61–17
$9d_{3/2}$	7.16–12	4.03–12	2.27–12	1.28–12	7.20–13	4.05–13	2.27–13	1.25–13	6.49–14	2.88–14	9.98–15	2.59–15	4.85–16	5.96–17	4.29–18
$9d_{5/2}$	1.08–11	6.07–12	3.42–12	1.92–12	1.08–12	6.08–13	3.41–13	1.87–13	9.55–14	4.16–14	1.41–14	3.59–15	6.62–16	8.02–17	5.72–18
$9f_{5/2}$	1.23–11	6.94–12	3.91–12	2.20–12	1.23–12	6.86–13	3.72–13	1.88–13	8.17–14	2.78–14	7.25–15	1.48–15	2.38–16	2.66–17	1.81–18
$9f_{7/2}$	1.63–11	9.18–12	5.17–12	2.91–12	1.63–12	9.07–13	4.92–13	2.48–13	1.07–13	3.62–14	9.40–15	1.92–15	3.06–16	3.42–17	2.32–18
$9g_{7/2}$	1.41–11	7.92–12	4.46–12	2.50–12	1.39–12	7.61–13	3.92–13	1.77–13	6.32–14	1.73–14	3.75–15	6.85–16	1.04–16	1.14–17	7.65–19
$9g_{9/2}$	1.75–11	9.84–12	5.54–12	3.11–12	1.73–12	9.46–13	4.87–13	2.19–13	7.83–14	2.14–14	4.63–15	8.46–16	1.28–16	1.40–17	9.44–19
$9h_{9/2}$	1.29–11	7.29–12	4.10–12	2.30–12	1.27–12	6.79–13	3.30–13	1.33–13	4.09–14	9.69–15	1.91–15	3.34–16	4.97–17	5.41–18	3.63–19
$9h_{11/2}$	1.55–11	8.71–12	4.91–12	2.75–12	1.52–12	8.12–13	3.95–13	1.59–13	4.89–14	1.16–14	2.29–15	3.99–16	5.94–17	6.45–18	4.33–19
$9i_{11/2}$	9.63–12	5.42–12	3.05–12	1.70–12	9.34–13	4.86–13	2.22–13	8.06–14	2.20–14	4.76–15	8.98–16	1.54–16	2.27–17	2.46–18	1.65–19
$9i_{13/2}$	1.12–11	6.31–12	3.55–12	1.98–12	1.09–12	5.65–13	2.59–13	9.37–14	2.56–14	5.54–15	1.04–15	1.79–16	2.64–17	2.86–18	1.92–19
$10s_{1/2}$	1.56–12	8.78–13	4.95–13	2.79–13	1.57–13	8.83–14	4.97–14	2.79–14	1.55–14	8.52–15	4.53–15	2.13–15	7.60–16	1.75–16	2.54–17
$10p_{1/2}$	1.67–12	9.42–13	5.31–13	2.99–13	1.69–13	9.52–14	5.41–14	3.10–14	1.78–14	9.87–15	4.85–15	1.87–15	5.13–16	8.84–17	9.27–18
$10p_{3/2}$	4.43–12	2.49–12	1.40–12	7.91–13	4.45–13	2.50–13	1.40–13	7.80–14	4.24–14	2.16–14	9.60–15	3.34–15	8.22–16	1.27–16	1.16–17
$10d_{3/2}$	5.30–12	2.98–12	1.68–12	9.47–13	5.33–13	3.00–13	1.68–13	9.25–14	4.77–14	2.10–14	7.29–15	1.89–15	3.54–16	4.34–17	3.11–18
$10d_{5/2}$	8.00–12	4.50–12	2.54–12	1.43–12	8.04–13	4.52–13	2.52–13	1.38–13	7.02–14	3.05–14	1.03–14	2.62–15	4.83–16	5.85–17	4.18–18
$10f_{5/2}$	9.32–12	5.25–12	2.96–12	1.66–12	9.33–13	5.19–13	2.81–13	1.42–13	6.15–14	2.09–14	5.44–15	1.11–15	1.78–16	1.99–17	1.35–18
$10f_{7/2}$	1.24–11	6.96–12	3.92–12	2.21–12	1.24–12	6.87–13	3.72–13	1.88–13	8.07–14	2.73–14	7.06–15	1.44–15	2.30–16	2.56–17	1.74–18
$10g_{7/2}$	1.12–11	6.33–12	3.57–12	2.00–12	1.12–12	6.09–13	3.13–13	1.41–13	5.03–14	1.37–14	2.98–15	5.44–16	8.25–17	9.02–18	6.07–19
$10g_{9/2}$	1.40–11	7.88–12	4.44–12	2.49–12	1.39–12	7.57–13	3.90–13	1.75–13	6.24–14	1.70–14	3.68–15	6.72–16	1.02–16	1.11–17	7.49–19
$10h_{9/2}$	1.12–11	6.32–12	3.56–12	1.99–12	1.10–12	5.89–13	2.86–13	1.15–13	3.54–14	8.37–15	1.65–15	2.88–16	4.29–17	4.67–18	3.13–19
$10h_{11/2}$	1.34–11	7.56–12	4.26–12	2.39–12	1.32–12	7.04–13	3.43–13	1.38–13	4.23–14	9.99–15	1.97–15	3.44–16	5.12–17	5.57–18	3.74–19
$10i_{11/2}$	9.58–12	5.39–12	3.03–12	1.70–12	9.30–13	4.83–13	2.21–13	8.01–14	2.18–14	4.73–15	8.92–16	1.53–16	2.26–17	2.45–18	1.64–19
$10i_{13/2}$	1.11–11	6.27–12	3.53–12	1.98–12	1.08–12	5.63–13	2.57–13	9.32–14	2.54–14	5.50–15	1.04–15	1.77–16	2.62–17	2.84–18	1.91–19
$11s_{1/2}$	1.20–12	6.75–13	3.81–13	2.14–13	1.21–13	6.79–14	3.81–14	2.13–14	1.17–14	6.37–15	3.37–15	1.58–15	5.63–16	1.29–16	1.88–17
$11p_{1/2}$	1.28–12	7.20–13	4.06–13	2.29–13	1.29–13	7.27–14	4.12–14	2.35–14	1.34–14	7.37–15	3.61–15	1.39–15	3.81–16	6.57–17	6.88–18
$11p_{3/2}$	3.41–12	1.92–12	1.08–12	6.09–13	3.42–13	1.92–13	1.07–13	5.94–14	3.20–14	1.62–14	7.18–15	2.49–15	6.13–16	9.46–17	8.67–18
$11d_{3/2}$	4.05–12	2.28–12	1.28–12	7.24–13	4.07–13	2.29–13	1.28–13	7.02–14	3.60–14	1.59–14	5.48–15	1.42–15	2.66–16	3.26–17	2.33–18
$11d_{5/2}$	6.12–12	3.45–12	1.94–12	1.09–12	6.16–13	3.46–13	1.93–13	1.05–13	5.32–14	2.30–14	7.78–15	1.97–15	3.63–16	4.40–17	3.12–18
$11f_{5/2}$	7.23–12	4.07–12	2.29–12	1.29–12	7.24–13	4.02–13	2.18–13	1.10–13	4.74–14	1.61–14	4.18–15	8.54–16	1.37–16	1.53–17	1.04–18
$11f_{7/2}$	9.59–12	5.40–12	3.04–12	1.71–12	9.61–13	5.34–13	2.89–13	1.45–13	6.22–14	2.10–14	5.42–15	1.10–15	1.76–16	1.97–17	1.33–18
$11g_{7/2}$	9.07–12	5.11–12	2.88–12	1.62–12	9.01–13	4.91–13	2.52–13	1.13–13	4.03–14	1.10–14	2.38–15	4.35–16	6.59–17	7.21–18	4.85–19
$11g_{9/2}$	1.13–11	6.36–12	3.58–12	2.01–12	1.12–12	6.11–13	3.14–13	1.41–13	5.00–14	1.36–14	2.94–15	5.37–16	8.14–17	8.90–18	5.99–19
$11h_{9/2}$	9.56–12	5.38–12	3.03–12	1.70–12	9.41–13	5.02–13	2.44–13	9.80–14	3.00–14	7.10–15	1.40–15	2.44–16	3.64–17	3.95–18	2.66–19
$11h_{11/2}$	1.14–11	6.45–12	3.63–12	2.04–12	1.13–12	6.01–13	2.92–13	1.17–13	3.59–14	8.48–15	1.67–15	2.92–16	4.34–17	4.72–18	3.17–19
$11i_{11/2}$	8.92–12	5.02–12	2.83–12	1.58–12	8.67–13	4.51–13	2.06–13	7.46–14	2.03–14	4.40–15	8.29–16	1.42–16	2.10–17	2.27–18	1.53–19
$11i_{13/2}$	1.04–11	5.85–12	3.29–12	1.84–12	1.01–12	5.25–13	2.40–13	8.68–14	2.36–14	5.11–15	9.64–16	1.65–16	2.44–17	2.64–18	1.77–19
$12s_{1/2}$	9.44–13	5.32–13	3.00–13	1.69–13	9.52–14	5.35–14	2.99–14	1.66–14	9.05–15	4.89–15	2.57–15	1.20–15	4.28–16	9.83–17	1.43–17
$12p_{1/2}$	1.00–12	5.65–13	3.18–13	1.80–13	1.01–13	5.70–14	3.22–14	1.82–14	1.03–14	5.65–15	2.76–15	1.06–15	2.91–16	5.01–17	5.26–18
$12p_{3/2}$	2.68–12	1.51–12	8.53–13	4.81–13	2.70–13	1.51–13	8.43–14	4.63–14	2.48–14	1.25–14	5.50–15	1.90–15	4.68–16	7.23–17	6.61–18
$12d_{3/2}$	3.17–12	1.78–12	1.01–12	5.67–13	3.19–13	1.79–13	1.00–13	5.46–14	2.79–14	1.22–14	4.22–15	1.09–15	2.04–16	2.51–17	1.80–18
$12d_{5/2}$	4.80–12	2.70–12	1.52–12	8.60–13	4.83–13	2.71–13	1.51–13	8.18–14	4.12–14	1.78–14	6.00–15	1.52–15	2.80–16	3.39–17	2.39–18
$12f_{5/2}$	5.72–12	3.22–12	1.82–12	1.02–12	5.74–13	3.19–13	1.72–13	8.65–14	3.72–14	1.26–14	3.27–15	6.68–16	1.07–16	1.20–17	8.33–19
$12f_{7/2}$	7.60–12	4.28–12	2.41–12	1.36–12	7.62–13	4.23–13	2.28–13	1.14–13	4.89–14	1.64–14	4.25–15	8.67–16	1.39–16	1.57–17	1.07–18
$12g_{7/2}$	7.38–12	4.16–12	2.35–12	1.32–12	7.35–13	4.00–13	2.05–13	9.18–14	3.26–14	8.87–15	1.92–15	3.51–16	5.32–17	5.81–18	3.91–19
$12g_{9/2}$	9.20–12	5.18–12	2.92–12	1.64–12	9.15–13	4.98–13	2.55–13	1.14–13	4.05–14	1.10–14	2.38–15	4.34–16	6.57–17	7.19–18	4.84–19
$12h_{9/2}$	8.09–12	4.56–12	2.57–12	1.44–12	7.98–13	4.25–13	2.06–13	8.28–14	2.53–14	5.98–15	1.18–15	2.06–16	3.06–17	3.33–18	2.24–19
$12h_{11/2}$	9.70–12	5.46–12	3.08–12	1.73–12	9.55–13	5.09–13	2.47–13	9.91–14	3.03–14	7.15–15	1.41–15	2.46–16	3.66–17	3.98–18	2.67–19
$12i_{11/2}$	8.04–12	4.53–12	2.55–12	1.43–12	7.82–13	4.06–13	1.86–13	6.71–14	1.83–14	3.95–15	7.45–16	1.27–16	1.88–17	2.04–18	1.37–19
$12i_{13/2}$	9.36–12	5.27–12	2.97–12	1.66–12	9.11–13	4.73–13	2.16–13	7.82–14	2.13–14	4.60–15	8.67–16	1.48–16	2.19–17	2.38–18	1.59–19
total	2.57–09	1.45–09	8.16–10	4.57–10	2.53–10	1.36–10	6.97–11	3.30–11	1.43–11	5.62–12	1.95–12	5.82–13	1.38–13	2.28–14	2.46–15
$\boldsymbol{W^{56+}}$															
$3d_{3/2}$	2.04–10	1.15–10	6.46–11	3.63–11	2.04–11	1.14–11	6.35–12	3.43–12	1.74–12	7.58–13	2.62–13	6.85–14	1.30–14	1.60–15	1.16–16
$3d_{5/2}$	2.86–10	1.61–10	9.04–11	5.08–11	2.85–11	1.60–11	8.86–12	4.79–12	2.41–12	1.04–12	3.56–13	9.13–14	1.70–14	2.08–15	1.49–16
$4s_{1/2}$	3.47–11	1.95–11	1.10–11	6.17–12	3.47–12	1.95–12	1.10–12	6.25–13	3.57–13	2.05–13	1.12–13	5.35–14	1.93–14	4.46–15	6.52–16
$4p_{1/2}$	4.45–11	2.51–11	1.41–11	7.93–12	4.46–12	2.51–12	1.41–12	7.99–13	4.51–13	2.46–13	1.19–13	4.58–14	1.25–14	2.17–15	2.30–16
$4p_{3/2}$	9.46–11	5.32–11	2.99–11	1.68–11	9.47–12	5.32–12	2.99–12	1.67–12	9.21–13	4.78–13	2.15–13	7.53–14	1.87–14	2.92–15	2.71–16
$4d_{3/2}$	1.01–10	5.67–11	3.19–11	1.79–11	1.01–11	5.64–12	3.14–12	1.71–12	8.71–13	3.86–13	1.35–13	3.55–14	6.74–15	8.35–16	6.05–17
$4d_{5/2}$	1.44–10	8.12–11	4.57–11	2.57–11	1.44–11	8.08–12	4.49–12	2.44–12	1.24–12	5.41–13	1.87–13	4.81–14	8.99–15	1.10–15	7.89–17
$4f_{5/2}$	7.95–11	4.47–11	2.51–11	1.41–11	7.92–12	4.41–12	2.40–12	1.23–12	5.52–13	1.97–13	5.37–14	1.13–14	1.83–15	2.06–16	1.41–17
$4f_{7/2}$	1.03–10	5.79–11	3.26–11	1.83–11	1.03–11	5.70–12	3.11–12	1.59–12	7.12–13	2.53–13	6.86–14	1.44–14	2.33–15	2.62–16	1.78–17
$5s_{1/2}$	1.78–11	1.00–11	5.64–12	3.17–12	1.79–12	1.01–12	5.67–13	3.22–13	1.84–13	1.04–13	5.63–14	2.65–14	9.45–15	2.17–15	3.16–16
$5p_{1/2}$	2.20–11	1.24–11	6.97–12	3.92–12	2.21–12	1.24–12	7.01–13	3.98–13	2.25–13	1.23–13	5.96–14	2.28–14	6.23–15	1.08–15	1.14–16

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$5p_{3/2}$	4.95–11	2.78–11	1.57–11	8.80–12	4.95–12	2.78–12	1.56–12	8.75–13	4.81–13	2.48–13	1.11–13	3.86–14	9.55–15	1.49–15	1.37–16
$5d_{3/2}$	5.58–11	3.14–11	1.76–11	9.92–12	5.57–12	3.12–12	1.74–12	9.49–13	4.86–13	2.15–13	7.55–14	1.98–14	3.76–15	4.66–16	3.37–17
$5d_{5/2}$	8.08–11	4.54–11	2.56–11	1.44–11	8.07–12	4.52–12	2.52–12	1.37–12	6.96–13	3.05–13	1.05–13	2.70–14	5.05–15	6.17–16	4.42–17
$5f_{5/2}$	6.35–11	3.57–11	2.01–11	1.13–11	6.33–12	3.52–12	1.92–12	9.87–13	4.44–13	1.59–13	4.33–14	9.12–15	1.48–15	1.67–16	1.14–17
$5f_{7/2}$	8.27–11	4.65–11	2.62–11	1.47–11	8.24–12	4.59–12	2.50–12	1.28–12	5.75–13	2.05–13	5.56–14	1.17–14	1.89–15	2.13–16	1.45–17
$5g_{7/2}$	3.24–11	1.82–11	1.02–11	5.75–12	3.21–12	1.77–12	9.34–13	4.44–13	1.73–13	5.14–14	1.18–14	2.23–15	3.42–16	3.76–17	2.53–18
$5g_{9/2}$	3.99–11	2.25–11	1.26–11	7.09–12	3.96–12	2.18–12	1.15–12	5.47–13	2.13–13	6.32–14	1.45–14	2.73–15	4.19–16	4.60–17	3.10–18
$6s_{1/2}$	1.06–11	5.94–12	3.34–12	1.88–12	1.06–12	5.96–13	3.36–13	1.90–13	1.08–13	6.06–14	3.23–14	1.50–14	5.32–15	1.22–15	1.77–16
$6p_{1/2}$	1.27–11	7.14–12	4.02–12	2.26–12	1.27–12	7.16–13	4.05–13	2.30–13	1.30–13	7.09–14	3.41–14	1.30–14	3.54–15	6.11–16	6.44–17
$6p_{3/2}$	2.95–11	1.66–11	9.34–12	5.26–12	2.96–12	1.66–12	9.34–13	5.22–13	2.86–13	1.46–13	6.46–14	2.23–14	5.51–15	8.54–16	7.87–17
$6d_{3/2}$	3.40–11	1.91–11	1.07–11	6.04–12	3.40–12	1.90–12	1.06–12	5.79–13	2.96–13	1.31–13	4.58–14	1.20–14	2.28–15	2.82–16	2.04–17
$6d_{5/2}$	4.96–11	2.79–11	1.57–11	8.82–12	4.96–12	2.78–12	1.55–12	8.41–13	4.27–13	1.87–13	6.40–14	1.65–14	3.07–15	3.74–16	2.69–17
$6f_{5/2}$	4.50–11	2.53–11	1.42–11	8.01–12	4.49–12	2.50–12	1.36–12	7.02–13	3.16–13	1.13–13	3.08–14	6.47–15	1.05–15	1.18–16	8.06–18
$6f_{7/2}$	5.89–11	3.32–11	1.87–11	1.05–11	5.88–12	3.27–12	1.78–12	9.16–13	4.11–13	1.46–13	3.96–14	8.31–15	1.35–15	1.51–16	1.03–17
$6g_{7/2}$	3.62–11	2.03–11	1.14–11	6.42–12	3.59–12	1.98–12	1.04–12	4.97–13	1.94–13	5.75–14	1.32–14	2.49–15	3.82–16	4.20–17	2.83–18
$6g_{9/2}$	4.47–11	2.51–11	1.41–11	7.94–12	4.44–12	2.44–12	1.29–12	6.14–13	2.39–13	7.08–14	1.63–14	3.06–15	4.69–16	5.15–17	3.47–18
$6h_{9/2}$	1.52–11	8.56–12	4.81–12	2.70–12	1.50–12	8.14–13	4.13–13	1.80–13	6.10–14	1.57–14	3.25–15	5.79–16	8.68–17	9.45–18	6.35–19
$6h_{11/2}$	1.81–11	1.02–11	5.73–12	3.21–12	1.79–12	9.69–13	4.91–13	2.14–13	7.25–14	1.86–14	3.86–15	6.87–16	1.03–16	1.12–17	7.54–19
$7s_{1/2}$	6.85–12	3.85–12	2.17–12	1.22–12	6.87–13	3.87–13	2.18–13	1.23–13	6.94–14	3.84–14	2.02–14	9.32–15	3.29–15	7.51–16	1.09–16
$7p_{1/2}$	8.07–12	4.54–12	2.55–12	1.44–12	8.09–13	4.56–13	2.57–13	1.46–13	8.25–14	4.47–14	2.13–14	8.09–15	2.20–15	3.79–16	3.99–17
$7p_{3/2}$	1.93–11	1.08–11	6.10–12	3.43–12	1.93–12	1.08–12	6.08–13	3.39–13	1.84–13	9.34–14	4.09–14	1.41–14	3.46–15	5.35–16	4.92–17
$7d_{3/2}$	2.23–11	1.25–11	7.05–12	3.97–12	2.23–12	1.25–12	6.97–13	3.80–13	1.94–13	8.55–14	2.98–14	7.78–15	1.47–15	1.82–16	1.32–17
$7d_{5/2}$	3.27–11	1.84–11	1.03–11	5.82–12	3.27–12	1.83–12	1.02–12	5.54–13	2.81–13	1.22–13	4.17–14	1.07–14	1.99–15	2.43–16	1.74–17
$7f_{5/2}$	3.19–11	1.80–11	1.01–11	5.68–12	3.19–12	1.78–12	9.68–13	4.98–13	2.24–13	8.00–14	2.18–14	4.57–15	7.43–16	8.36–17	5.69–18
$7f_{7/2}$	4.20–11	2.36–11	1.33–11	7.47–12	4.19–12	2.33–12	1.27–12	6.53–13	2.92–13	1.04–13	2.81–14	5.88–15	9.52–16	1.07–16	7.28–18
$7g_{7/2}$	3.14–11	1.77–11	9.93–12	5.58–12	3.12–12	1.72–12	9.07–13	4.32–13	1.68–13	4.99–14	1.15–14	2.16–15	3.31–16	3.63–17	2.45–18
$7g_{9/2}$	3.89–11	2.19–11	1.23–11	6.91–12	3.86–12	2.12–12	1.12–12	5.34–13	2.07–13	6.14–14	1.41–14	2.65–15	4.06–16	4.46–17	3.01–18
$7h_{9/2}$	2.11–11	1.19–11	6.68–12	3.74–12	2.08–12	1.13–12	5.73–13	2.50–13	8.47–14	2.18–14	4.51–15	8.03–16	1.20–16	1.31–17	8.82–19
$7h_{11/2}$	2.52–11	1.41–11	7.96–12	4.47–12	2.48–12	1.35–12	6.83–13	2.98–13	1.01–13	2.59–14	5.36–15	9.54–16	1.43–16	1.56–17	1.05–18
$7i_{11/2}$	7.62–12	4.29–12	2.41–12	1.35–12	7.46–13	3.97–13	1.92–13	7.63–14	2.29–14	5.32–15	1.04–15	1.80–16	2.67–17	2.90–18	1.95–19
$7i_{13/2}$	8.85–12	4.98–12	2.80–12	1.57–12	8.65–13	4.61–13	2.23–13	8.85–14	2.66–14	6.16–15	1.20–15	2.08–16	3.09–17	3.36–18	2.25–19
$8s_{1/2}$	4.74–12	2.67–12	1.50–12	8.45–13	4.75–13	2.68–13	1.51–13	8.48–14	4.74–14	2.59–14	1.35–14	6.18–15	2.17–15	4.95–16	7.15–17
$8p_{1/2}$	5.49–12	3.09–12	1.74–12	9.80–13	5.51–13	3.10–13	1.75–13	9.93–14	5.58–14	3.00–14	1.42–14	5.38–15	1.46–15	2.51–16	2.65–17
$8p_{3/2}$	1.34–11	7.52–12	4.23–12	2.38–12	1.34–12	7.53–13	4.22–13	2.34–13	1.26–13	6.34–14	2.75–14	9.43–15	2.31–15	3.57–16	3.28–17
$8d_{3/2}$	1.55–11	8.70–12	4.90–12	2.75–12	1.55–12	8.68–13	4.83–13	2.63–13	1.34–13	5.87–14	2.04–14	5.31–15	1.00–15	1.24–16	8.98–18
$8d_{5/2}$	2.28–11	1.28–11	7.20–12	4.05–12	2.28–12	1.28–12	7.10–13	3.85–13	1.94–13	8.39–14	2.86–14	7.31–15	1.36–15	1.66–16	1.19–17
$8f_{5/2}$	2.32–11	1.31–11	7.35–12	4.13–12	2.32–12	1.29–12	7.04–13	3.62–13	1.62–13	5.78–14	1.57–14	3.29–15	5.35–16	6.02–17	4.15–18
$8f_{7/2}$	3.06–11	1.72–11	9.68–12	5.44–12	3.05–12	1.70–12	9.25–13	4.75–13	2.12–13	7.52–14	2.03–14	4.24–15	6.87–16	7.72–17	5.25–18
$8g_{7/2}$	2.55–11	1.43–11	8.07–12	4.53–12	2.53–12	1.39–12	7.37–13	3.50–13	1.36–13	4.04–14	9.27–15	1.74–15	2.67–16	2.93–17	1.98–18
$8g_{9/2}$	3.16–11	1.78–11	1.00–11	5.62–12	3.14–12	1.73–12	9.13–13	4.34–13	1.68–13	4.98–14	1.14–14	2.14–15	3.28–16	3.60–17	2.43–18
$8h_{9/2}$	2.13–11	1.20–11	6.74–12	3.78–12	2.10–12	1.14–12	5.78–13	2.52–13	8.54–14	2.19–14	4.54–15	8.08–16	1.21–16	1.32–17	8.87–19
$8h_{11/2}$	2.54–11	1.43–11	8.04–12	4.51–12	2.51–12	1.36–12	6.90–13	3.00–13	1.02–13	2.61–14	5.40–15	9.61–16	1.44–16	1.57–17	1.05–18
$8i_{11/2}$	1.26–11	7.08–12	3.98–12	2.23–12	1.23–12	6.55–13	3.17–13	1.26–13	3.79–14	8.78–15	1.71–15	2.97–16	4.40–17	4.78–18	3.21–19
$8i_{13/2}$	1.46–11	8.22–12	4.62–12	2.59–12	1.43–12	7.61–13	3.68–13	1.46–13	4.40–14	1.02–14	1.98–15	3.44–16	5.10–17	5.54–18	3.72–19
$9s_{1/2}$	3.44–12	1.94–12	1.09–12	6.13–13	3.45–13	1.94–13	1.09–13	6.11–14	3.38–14	1.83–14	9.45–15	4.30–15	1.51–15	3.43–16	4.96–17
$9p_{1/2}$	3.94–12	2.22–12	1.25–12	7.02–13	3.95–13	2.23–13	1.26–13	7.09–14	3.96–14	2.11–14	9.96–15	3.75–15	1.02–15	1.75–16	1.83–17
$9p_{3/2}$	9.72–12	5.47–12	3.08–12	1.73–12	9.74–13	5.47–13	3.06–13	1.69–13	9.04–14	4.50–14	1.94–14	6.62–15	1.62–15	2.50–16	2.30–17
$9d_{3/2}$	1.12–11	6.31–12	3.55–12	2.00–12	1.12–12	6.30–13	3.50–13	1.90–13	9.63–14	4.20–14	1.45–14	3.78–15	7.14–16	8.81–17	6.36–18
$9d_{5/2}$	1.66–11	9.31–12	5.24–12	2.95–12	1.66–12	9.29–13	5.16–13	2.79–13	1.40–13	6.02–14	2.04–14	5.21–15	9.67–16	1.18–16	8.45–18
$9f_{5/2}$	1.73–11	9.74–12	5.48–12	3.09–12	1.73–12	9.63–13	5.25–13	2.69–13	1.20–13	4.28–14	1.16–14	2.43–15	3.95–16	4.44–17	3.02–18
$9f_{7/2}$	2.28–11	1.29–11	7.24–12	4.07–12	2.28–12	1.27–12	6.91–13	3.54–13	1.58–13	5.57–14	1.50–14	3.13–15	5.07–16	5.70–17	3.88–18
$9g_{7/2}$	2.04–11	1.15–11	6.44–12	3.62–12	2.02–12	1.11–12	5.89–13	2.80–13	1.08–13	3.21–14	7.36–15	1.38–15	2.12–16	2.33–17	1.57–18
$9g_{9/2}$	2.53–11	1.42–11	8.01–12	4.50–12	2.51–12	1.38–12	7.30–13	3.46–13	1.34–13	3.96–14	9.06–15	1.70–15	2.61–16	2.86–17	1.93–18
$9h_{9/2}$	1.93–11	1.08–11	6.10–12	3.42–12	1.90–12	1.03–12	5.24–13	2.28–13	7.71–14	1.98–14	4.09–15	7.29–16	1.09–16	1.19–17	8.00–19
$9h_{11/2}$	2.30–11	1.29–11	7.29–12	4.09–12	2.27–12	1.23–12	6.25–13	2.72–13	9.19–14	2.36–14	4.87–15	8.67–16	1.30–16	1.42–17	9.51–19
$9i_{11/2}$	1.44–11	8.09–12	4.55–12	2.55–12	1.41–12	7.50–13	3.63–13	1.44–13	4.33–14	1.00–14	1.95–15	3.39–16	5.03–17	5.46–18	3.66–19
$9i_{13/2}$	1.67–11	9.40–12	5.29–12	2.96–12	1.64–12	8.71–13	4.21–13	1.67–13	5.02–14	1.16–14	2.27–15	3.93–16	5.83–17	6.33–18	4.25–19
$10s_{1/2}$	2.59–12	1.46–12	8.20–13	4.62–13	2.60–13	1.46–13	8.19–14	4.56–14	2.51–14	1.34–14	6.87–15	3.11–15	1.09–15	2.47–16	3.57–17
$10p_{1/2}$	2.93–12	1.65–12	9.30–13	5.24–13	2.95–13	1.66–13	9.34–14	5.25–14	2.92–14	1.54–14	7.24–15	2.72–15	7.36–16	1.26–16	1.33–17
$10p_{3/2}$	7.33–12	4.12–12	2.32–12	1.31–12	7.35–13	4.12–13	2.30–13	1.26–13	6.70–14	3.31–14	1.42–14	4.82–15	1.18–15	1.82–16	1.67–17
$10d_{3/2}$	8.43–12	4.74–12	2.67–12	1.50–12	8.45–13	4.73–13	2.63–13	1.42–13	7.16–14	3.11–14	1.07–14	2.78–15	5.25–16	6.48–17	4.69–18
$10d_{5/2}$	1.25–11	7.01–12	3.95–12	2.22–12	1.25–12	6.99–13	3.88–13	2.09–13	1.04–13	4.46–14	1.51–14	3.84–15	7.12–16	8.67–17	6.21–18
$10f_{5/2}$	1.32–11	7.45–12	4.20–12	2.36–12	1.32–12	7.37–13	4.01–13	2.05–13	9.15–14	3.24–14	8.76–15	1.84–15	2.98–16	3.35–17	2.28–18
$10f_{7/2}$	1.75–11	9.85–12	5.55–12	3.12–12	1.75–12	9.73–13	5.29–13	2.70–13	1.20–13	4.23–14	1.14–14	2.37–15	3.83–16	4.30–17	2.92–18
$10g_{7/2}$	1.63–11	9.17–12	5.16–12	2.90–12	1.62–12	8.93–13	4.71–13	2.23–13	8.64–14	2.55–14	5.85–15	1.10–15	1.68–16	1.85–17	1.25–18

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T\,(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$10g_{9/2}$	2.02–11	1.14–11	6.41–12	3.60–12	2.01–12	1.11–12	5.84–13	2.77–13	1.07–13	3.15–14	7.20–15	1.35–15	2.07–16	2.27–17	1.53–18
$10h_{9/2}$	1.67–11	9.40–12	5.29–12	2.97–12	1.65–12	8.95–13	4.54–13	1.97–13	6.67–14	1.71–14	3.53–15	6.28–16	9.42–17	1.03–17	6.90–19
$10h_{11/2}$	1.99–11	1.12–11	6.32–12	3.55–12	1.97–12	1.07–12	5.42–13	2.35–13	7.95–14	2.04–14	4.21–15	7.48–16	1.12–16	1.22–17	8.21–19
$10i_{11/2}$	1.43–11	8.04–12	4.52–12	2.54–12	1.40–12	7.46–13	3.60–13	1.43–13	4.30–14	9.95–15	1.94–15	3.36–16	4.99–17	5.41–18	3.63–19
$10i_{13/2}$	1.66–11	9.35–12	5.26–12	2.95–12	1.63–12	8.67–13	4.19–13	1.66–13	4.99–14	1.15–14	2.25–15	3.90–16	5.78–17	6.28–18	4.22–19
$11s_{1/2}$	2.00–12	1.13–12	6.35–13	3.58–13	2.01–13	1.13–13	6.32–14	3.50–14	1.91–14	1.01–14	5.15–15	2.32–15	8.10–16	1.84–16	2.66–17
$11p_{1/2}$	2.26–12	1.27–12	7.16–13	4.03–13	2.27–13	1.28–13	7.17–14	4.01–14	2.21–14	1.16–14	5.43–15	2.03–15	5.50–16	9.45–17	9.93–18
$11p_{3/2}$	5.69–12	3.20–12	1.80–12	1.01–12	5.70–13	3.20–13	1.78–13	9.71–14	5.11–14	2.50–14	1.07–14	3.62–15	8.83–16	1.36–16	1.25–17
$11d_{3/2}$	6.52–12	3.67–12	2.07–12	1.16–12	6.54–13	3.66–13	2.03–13	1.09–13	5.47–14	2.36–14	8.10–15	2.10–15	3.97–16	4.90–17	3.52–18
$11d_{5/2}$	9.65–12	5.43–12	3.06–12	1.72–12	9.68–13	5.41–13	2.99–13	1.61–13	7.97–14	3.39–14	1.14–14	2.90–15	5.38–16	6.56–17	4.70–18
$11f_{5/2}$	1.04–11	5.83–12	3.29–12	1.85–12	1.04–12	5.77–13	3.13–13	1.60–13	7.10–14	2.51–14	6.77–15	1.42–15	2.30–16	2.58–17	1.75–18
$11f_{7/2}$	1.37–11	7.72–12	4.35–12	2.44–12	1.37–12	7.62–13	4.14–13	2.11–13	9.32–14	3.27–14	8.77–15	1.83–15	2.96–16	3.32–17	2.26–18
$11g_{7/2}$	1.32–11	7.41–12	4.17–12	2.34–12	1.31–12	7.20–13	3.80–13	1.80–13	6.93–14	2.04–14	4.68–15	8.78–16	1.35–16	1.48–17	9.95–19
$11g_{9/2}$	1.63–11	9.20–12	5.18–12	2.91–12	1.63–12	8.95–13	4.71–13	2.23–13	8.59–14	2.52–14	5.77–15	1.08–15	1.66–16	1.82–17	1.23–18
$11h_{9/2}$	1.42–11	8.01–12	4.51–12	2.53–12	1.41–12	7.63–13	3.86–13	1.68–13	5.66–14	1.45–14	2.99–15	5.32–16	7.98–17	8.69–18	5.84–19
$11h_{11/2}$	1.70–11	9.57–12	5.39–12	3.02–12	1.68–12	9.12–13	4.62–13	2.00–13	6.75–14	1.73–14	3.57–15	6.34–16	9.50–17	1.04–17	6.96–19
$11i_{11/2}$	1.33–11	7.49–12	4.22–12	2.36–12	1.31–12	6.95–13	3.36–13	1.33–13	3.99–14	9.24–15	1.80–15	3.12–16	4.63–17	5.03–18	3.37–19
$11i_{13/2}$	1.55–11	8.71–12	4.91–12	2.75–12	1.52–12	8.08–13	3.90–13	1.55–13	4.64–14	1.07–14	2.09–15	3.62–16	5.37–17	5.84–18	3.92–19
$12s_{1/2}$	1.59–12	8.94–13	5.04–13	2.84–13	1.60–13	8.95–14	4.99–14	2.75–14	1.48–14	7.82–15	3.95–15	1.78–15	6.19–16	1.41–16	2.03–17
$12p_{1/2}$	1.78–12	1.00–12	5.64–13	3.18–13	1.79–13	1.00–13	5.63–14	3.13–14	1.72–14	8.96–15	4.17–15	1.56–15	4.21–16	7.23–17	7.62–18
$12p_{3/2}$	4.51–12	2.54–12	1.43–12	8.06–13	4.53–13	2.53–13	1.40–13	7.63–14	3.99–14	1.94–14	8.24–15	2.78–15	6.78–16	1.04–16	9.56–18
$12d_{3/2}$	5.16–12	2.90–12	1.64–12	9.21–13	5.17–13	2.89–13	1.60–13	8.57–14	4.27–14	1.83–14	6.28–15	1.63–15	3.07–16	3.78–17	2.72–18
$12d_{5/2}$	7.65–12	4.31–12	2.43–12	1.37–12	7.67–13	4.29–13	2.36–13	1.26–13	6.23–14	2.64–14	8.86–15	2.25–15	4.17–16	5.08–17	3.64–18
$12f_{5/2}$	8.27–12	4.65–12	2.62–12	1.48–12	8.27–13	4.60–13	2.49–13	1.27–13	5.61–14	1.98–14	5.32–15	1.11–15	1.80–16	2.02–17	1.37–18
$12f_{7/2}$	1.09–11	6.16–12	3.47–12	1.95–12	1.09–12	6.08–13	3.30–13	1.67–13	7.37–14	2.58–14	6.90–15	1.44–15	2.34–16	2.63–17	1.79–18
$12g_{7/2}$	1.07–11	6.04–12	3.40–12	1.91–12	1.07–12	5.87–13	3.09–13	1.46–13	5.62–14	1.65–14	3.78–15	7.08–16	1.09–16	1.19–17	8.03–19
$12g_{9/2}$	1.33–11	7.51–12	4.23–12	2.38–12	1.33–12	7.31–13	3.84–13	1.81–13	6.96–14	2.04–14	4.66–15	8.73–16	1.34–16	1.47–17	9.89–19
$12h_{9/2}$	1.20–11	6.78–12	3.82–12	2.15–12	1.19–12	6.46–13	3.27–13	1.42–13	4.77–14	1.22–14	2.52–15	4.48–16	6.72–17	7.32–18	4.92–19
$12h_{11/2}$	1.44–11	8.12–12	4.57–12	2.57–12	1.43–12	7.73–13	3.91–13	1.69–13	5.70–14	1.46–14	3.00–15	5.34–16	8.00–17	8.72–18	5.86–19
$12i_{11/2}$	1.20–11	6.75–12	3.80–12	2.13–12	1.18–12	6.27–13	3.03–13	1.20–13	3.59–14	8.31–15	1.62–15	2.80–16	4.16–17	4.52–18	3.03–19
$12i_{13/2}$	1.40–11	7.86–12	4.43–12	2.48–12	1.37–12	7.29–13	3.52–13	1.39–13	4.18–14	9.65–15	1.88–15	3.25–16	4.83–17	5.24–18	3.52–19
total	4.17–09	2.34–09	1.32–09	7.40–10	4.12–10	2.25–10	1.18–10	5.74–11	2.56–11	1.01–11	3.43–12	9.78–13	2.21–13	3.47–14	3.58–15
$\boldsymbol{W^{64+}}$															
$3s_{1/2}$	1.02–10	5.71–11	3.21–11	1.81–11	1.02–11	5.72–12	3.22–12	1.82–12	1.03–12	5.80–13	3.15–13	1.50–13	5.45–14	1.27–14	1.88–15
$3p_{1/2}$	1.33–10	7.46–11	4.20–11	2.36–11	1.33–11	7.46–12	4.19–12	2.35–12	1.30–12	6.90–13	3.28–13	1.25–13	3.45–14	6.02–15	6.43–16
$3p_{3/2}$	2.51–10	1.41–10	7.93–11	4.46–11	2.51–11	1.41–11	7.89–12	4.40–12	2.40–12	1.24–12	5.54–13	1.96–13	4.93–14	7.78–15	7.28–16
$3d_{3/2}$	1.90–10	1.07–10	6.00–11	3.37–11	1.89–11	1.06–11	5.90–12	3.20–12	1.63–12	7.26–13	2.57–13	6.88–14	1.33–14	1.66–15	1.21–16
$3d_{5/2}$	2.64–10	1.49–10	8.35–11	4.70–11	2.64–11	1.48–11	8.21–12	4.45–12	2.26–12	9.96–13	3.48–13	9.13–14	1.73–14	2.14–15	1.54–16
$4s_{1/2}$	4.42–11	2.48–11	1.40–11	7.85–12	4.42–12	2.49–12	1.40–12	7.91–13	4.48–13	2.52–13	1.35–13	6.34–14	2.26–14	5.23–15	7.63–16
$4p_{1/2}$	5.59–11	3.14–11	1.77–11	9.94–12	5.59–12	3.14–12	1.77–12	9.93–13	5.53–13	2.96–13	1.41–13	5.37–14	1.47–14	2.56–15	2.72–16
$4p_{3/2}$	1.15–10	6.46–11	3.63–11	2.04–11	1.15–11	6.45–12	3.62–12	2.02–12	1.10–12	5.66–13	2.52–13	8.81–14	2.20–14	3.45–15	3.21–16
$4d_{3/2}$	1.11–10	6.22–11	3.50–11	1.97–11	1.10–11	6.19–12	3.44–12	1.87–12	9.58–13	4.27–13	1.51–13	4.03–14	7.76–15	9.69–16	7.06–17
$4d_{5/2}$	1.57–10	8.81–11	4.96–11	2.79–11	1.57–11	8.77–12	4.88–12	2.65–12	1.35–12	5.93–13	2.07–13	5.42–14	1.02–14	1.26–15	9.12–17
$4f_{5/2}$	8.18–11	4.60–11	2.59–11	1.45–11	8.16–12	4.55–12	2.49–12	1.29–12	5.93–13	2.19–13	6.15–14	1.32–14	2.18–15	2.47–16	1.68–17
$4f_{7/2}$	1.06–10	5.96–11	3.35–11	1.88–11	1.06–11	5.88–12	3.22–12	1.67–12	7.64–13	2.81–13	7.86–14	1.69–14	2.77–15	3.13–16	2.13–17
$5s_{1/2}$	2.35–11	1.32–11	7.45–12	4.19–12	2.36–12	1.33–12	7.47–13	4.22–13	2.38–13	1.33–13	7.04–14	3.25–14	1.15–14	2.63–15	3.81–16
$5p_{1/2}$	2.90–11	1.63–11	9.18–12	5.16–12	2.90–12	1.63–12	9.19–13	5.17–13	2.89–13	1.55–13	7.32–14	2.77–14	7.57–15	1.31–15	1.39–16
$5p_{3/2}$	6.27–11	3.53–11	1.98–11	1.12–11	6.28–12	3.53–12	1.98–12	1.10–12	6.00–13	3.06–13	1.35–13	4.67–14	1.16–14	1.81–15	1.67–16
$5d_{3/2}$	6.54–11	3.68–11	2.07–11	1.16–11	6.54–12	3.67–12	2.04–12	1.11–12	5.68–13	2.52–13	8.91–14	2.37–14	4.54–15	5.67–16	4.12–17
$5d_{5/2}$	9.38–11	5.28–11	2.97–11	1.67–11	9.38–12	5.26–12	2.92–12	1.59–12	8.06–13	3.54–13	1.23–13	3.20–14	6.04–15	7.43–16	5.36–17
$5f_{5/2}$	7.06–11	3.97–11	2.23–11	1.25–11	7.04–12	3.92–12	2.15–12	1.12–12	5.12–13	1.89–13	5.31–14	1.14–14	1.88–15	2.13–16	1.45–17
$5f_{7/2}$	9.19–11	5.17–11	2.91–11	1.63–11	9.16–12	5.11–12	2.79–12	1.45–12	6.64–13	2.44–13	6.82–14	1.46–14	2.39–15	2.70–16	1.84–17
$5g_{7/2}$	3.96–11	2.23–11	1.25–11	7.03–12	3.94–12	2.18–12	1.16–12	5.69–13	2.32–13	7.25–14	1.73–14	3.32–15	5.14–16	5.67–17	3.82–18
$5g_{9/2}$	4.87–11	2.74–11	1.54–11	8.65–12	4.84–12	2.68–12	1.43–12	6.99–13	2.85–13	8.88–14	2.12–14	4.06–15	6.27–16	6.91–17	4.66–18
$6s_{1/2}$	1.42–11	7.99–12	4.50–12	2.53–12	1.42–12	8.01–13	4.51–13	2.54–13	1.43–13	7.91–14	4.12–14	1.88–14	6.57–15	1.50–15	2.17–16
$6p_{1/2}$	1.71–11	9.64–12	5.42–12	3.05–12	1.72–12	9.66–13	5.44–13	3.06–13	1.71–13	9.11–14	4.28–14	1.61–14	4.38–15	7.57–16	8.01–17
$6p_{3/2}$	3.84–11	2.16–11	1.22–11	6.84–12	3.84–12	2.16–12	1.21–12	6.73–13	3.65–13	1.84–13	8.04–14	2.76–14	6.81–15	1.06–15	9.78–17
$6d_{3/2}$	4.15–11	2.33–11	1.31–11	7.38–12	4.14–12	2.32–12	1.29–12	7.03–13	3.59–13	1.59–13	5.58–14	1.48–14	2.82–15	3.52–16	2.56–17
$6d_{5/2}$	5.99–11	3.37–11	1.89–11	1.06–11	5.98–12	3.35–12	1.86–12	1.01–12	5.12–13	2.24–13	7.73–14	2.01–14	3.77–15	4.63–16	3.34–17
$6f_{5/2}$	5.21–11	2.93–11	1.65–11	9.27–12	5.20–12	2.90–12	1.59–12	8.24–13	3.78–13	1.39–13	3.90–14	8.36–15	1.37–15	1.56–16	1.06–17
$6f_{7/2}$	6.82–11	3.84–11	2.16–11	1.21–11	6.80–12	3.79–12	2.07–12	1.07–12	4.92–13	1.80–13	5.02–14	1.07–14	1.76–15	1.99–16	1.35–17
$6g_{7/2}$	4.44–11	2.50–11	1.41–11	7.90–12	4.42–12	2.44–12	1.31–12	6.39–13	2.60–13	8.13–14	1.94–14	3.72–15	5.76–16	6.35–17	4.28–18
$6g_{9/2}$	5.48–11	3.08–11	1.74–11	9.74–12	5.45–12	3.01–12	1.61–12	7.87–13	3.20–13	9.99–14	2.38–14	4.56–15	7.05–16	7.76–17	5.24–18
$6h_{9/2}$	1.98–11	1.12–11	6.27–12	3.52–12	1.96–12	1.07–12	5.56–13	2.53–13	9.13–14	2.49–14	5.34–15	9.66–16	1.46–16	1.59–17	1.07–18
$6h_{11/2}$	2.36–11	1.32–11	7.45–12	4.18–12	2.33–12	1.27–12	6.60–13	3.00–13	1.08–13	2.95–14	6.32–15	1.14–15	1.72–16	1.88–17	1.27–18

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$7s_{1/2}$	9.34–12	5.25–12	2.96–12	1.66–12	9.36–13	5.27–13	2.96–13	1.67–13	9.32–14	5.09–14	2.62–14	1.18–14	4.11–15	9.35–16	1.35–16
$7p_{1/2}$	1.11–11	6.23–12	3.51–12	1.97–12	1.11–12	6.24–13	3.51–13	1.98–13	1.10–13	5.82–14	2.72–14	1.02–14	2.76–15	4.75–16	5.02–17
$7p_{3/2}$	2.55–11	1.43–11	8.06–12	4.53–12	2.55–12	1.43–12	8.02–13	4.45–13	2.40–13	1.20–13	5.17–14	1.76–14	4.33–15	6.71–16	6.19–17
$7d_{3/2}$	2.79–11	1.57–11	8.83–12	4.96–12	2.79–12	1.56–12	8.69–13	4.72–13	2.40–13	1.06–13	3.69–14	9.72–15	1.86–15	2.31–16	1.68–17
$7d_{5/2}$	4.05–11	2.28–11	1.28–11	7.21–12	4.05–12	2.27–12	1.26–12	6.81–13	3.44–13	1.49–13	5.13–14	1.33–14	2.49–15	3.05–16	2.20–17
$7f_{5/2}$	3.80–11	2.14–11	1.20–11	6.76–12	3.79–12	2.11–12	1.16–12	5.99–13	2.74–13	1.01–13	2.81–14	6.02–15	9.89–16	1.12–16	7.63–18
$7f_{7/2}$	4.98–11	2.80–11	1.58–11	8.86–12	4.97–12	2.77–12	1.51–12	7.84–13	3.58–13	1.31–13	3.63–14	7.74–15	1.27–15	1.43–16	9.75–18
$7g_{7/2}$	3.88–11	2.18–11	1.23–11	6.90–12	3.86–12	2.14–12	1.14–12	5.58–13	2.27–13	7.09–14	1.69–14	3.24–15	5.01–16	5.52–17	3.72–18
$7g_{9/2}$	4.80–11	2.70–11	1.52–11	8.53–12	4.77–12	2.64–12	1.41–12	6.89–13	2.80–13	8.72–14	2.07–14	3.97–15	6.14–16	6.76–17	4.56–18
$7h_{9/2}$	2.74–11	1.54–11	8.67–12	4.87–12	2.71–12	1.48–12	7.69–13	3.50–13	1.26–13	3.44–14	7.38–15	1.34–15	2.01–16	2.20–17	1.48–18
$7h_{11/2}$	3.26–11	1.83–11	1.03–11	5.79–12	3.23–12	1.76–12	9.14–13	4.16–13	1.50–13	4.08–14	8.75–15	1.58–15	2.39–16	2.61–17	1.75–18
$7i_{11/2}$	1.00–11	5.64–12	3.17–12	1.78–12	9.87–13	5.32–13	2.65–13	1.11–13	3.58–14	8.75–15	1.75–15	3.08–16	4.59–17	4.99–18	3.35–19
$7i_{13/2}$	1.16–11	6.54–12	3.68–12	2.06–12	1.14–12	6.16–13	3.07–13	1.29–13	4.15–14	1.01–14	2.03–15	3.56–16	5.30–17	5.77–18	3.87–19
$8s_{1/2}$	6.53–12	3.67–12	2.07–12	1.16–12	6.54–13	3.68–13	2.07–13	1.16–13	6.43–14	3.47–14	1.77–14	7.91–15	2.74–15	6.21–16	8.95–17
$8p_{1/2}$	7.63–12	4.29–12	2.42–12	1.36–12	7.65–13	4.30–13	2.42–13	1.36–13	7.52–14	3.95–14	1.83–14	6.83–15	1.84–15	3.18–16	3.35–17
$8p_{3/2}$	1.79–11	1.01–11	5.67–12	3.19–12	1.79–12	1.01–12	5.62–13	3.11–13	1.66–13	8.23–14	3.52–14	1.19–14	2.92–15	4.52–16	4.16–17
$8d_{3/2}$	1.97–11	1.11–11	6.24–12	3.51–12	1.97–12	1.11–12	6.14–13	3.33–13	1.68–13	7.36–14	2.56–14	6.72–15	1.28–15	1.59–16	1.16–17
$8d_{5/2}$	2.87–11	1.62–11	9.09–12	5.11–12	2.87–12	1.61–12	8.92–13	4.82–13	2.42–13	1.04–13	3.57–14	9.18–15	1.72–15	2.11–16	1.52–17
$8f_{5/2}$	2.81–11	1.58–11	8.90–12	5.00–12	2.81–12	1.56–12	8.55–13	4.43–13	2.02–13	7.38–14	2.05–14	4.39–15	7.21–16	8.16–17	5.56–18
$8f_{7/2}$	3.69–11	2.08–11	1.17–11	6.57–12	3.69–12	2.05–12	1.12–12	5.80–13	2.64–13	9.60–14	2.66–14	5.66–15	9.25–16	1.04–16	7.12–18
$8g_{7/2}$	3.17–11	1.78–11	1.00–11	5.64–12	3.16–12	1.74–12	9.32–13	4.55–13	1.85–13	5.76–14	1.37–14	2.63–15	4.06–16	4.47–17	3.02–18
$8g_{9/2}$	3.93–11	2.21–11	1.24–11	6.98–12	3.91–12	2.16–12	1.15–12	5.63–13	2.28–13	7.09–14	1.68–14	3.22–15	4.98–16	5.49–17	3.70–18
$8h_{9/2}$	2.76–11	1.55–11	8.74–12	4.90–12	2.73–12	1.50–12	7.75–13	3.53–13	1.27–13	3.46–14	7.41–15	1.34–15	2.02–16	2.21–17	1.49–18
$8h_{11/2}$	3.29–11	1.85–11	1.04–11	5.84–12	3.26–12	1.78–12	9.22–13	4.20–13	1.51–13	4.11–14	8.80–15	1.59–15	2.40–16	2.62–17	1.76–18
$8i_{11/2}$	1.65–11	9.29–12	5.23–12	2.93–12	1.62–12	8.75–13	4.36–13	1.83–13	5.90–14	1.44–14	2.89–15	5.06–16	7.55–17	8.21–18	5.51–19
$8i_{13/2}$	1.92–11	1.08–11	6.06–12	3.40–12	1.88–12	1.02–12	5.06–13	2.13–13	6.83–14	1.67–14	3.34–15	5.86–16	8.73–17	9.50–18	6.38–19
$9s_{1/2}$	4.76–12	2.68–12	1.51–12	8.49–13	4.78–13	2.68–13	1.51–13	8.41–14	4.63–14	2.47–14	1.25–14	5.55–15	1.92–15	4.33–16	6.24–17
$9p_{1/2}$	5.52–12	3.10–12	1.75–12	9.83–13	5.53–13	3.11–13	1.75–13	9.79–14	5.38–14	2.81–14	1.29–14	4.80–15	1.29–15	2.22–16	2.34–17
$9p_{3/2}$	1.31–11	7.38–12	4.16–12	2.34–12	1.31–12	7.37–13	4.12–13	2.26–13	1.20–13	5.89–14	2.50–14	8.45–15	2.06–15	3.18–16	2.93–17
$9d_{3/2}$	1.45–11	8.16–12	4.59–12	2.58–12	1.45–12	8.13–13	4.51–13	2.43–13	1.22–13	5.32–14	1.84–14	4.82–15	9.18–16	1.14–16	8.22–18
$9d_{5/2}$	2.12–11	1.19–11	6.70–12	3.77–12	2.12–12	1.19–12	6.57–13	3.53–13	1.76–13	7.57–14	2.57–14	6.60–15	1.23–15	1.51–16	1.09–17
$9f_{5/2}$	2.13–11	1.20–11	6.73–12	3.79–12	2.12–12	1.18–12	6.46–13	3.34–13	1.52–13	5.52–14	1.53–14	3.27–15	5.37–16	6.07–17	4.14–18
$9f_{7/2}$	2.80–11	1.57–11	8.86–12	4.98–12	2.79–12	1.56–12	8.49–13	4.38–13	1.98–13	7.19–14	1.98–14	4.22–15	6.89–16	7.78–17	5.31–18
$9g_{7/2}$	2.55–11	1.43–11	8.07–12	4.53–12	2.54–12	1.40–12	7.48–13	3.65–13	1.48–13	4.60–14	1.09–14	2.09–15	3.23–16	3.56–17	2.40–18
$9g_{9/2}$	3.16–11	1.78–11	1.00–11	5.62–12	3.14–12	1.74–12	9.27–13	4.52–13	1.83–13	5.67–14	1.34–14	2.57–15	3.97–16	4.37–17	2.95–18
$9h_{9/2}$	2.50–11	1.41–11	7.91–12	4.44–12	2.48–12	1.35–12	7.01–13	3.19–13	1.15–13	3.12–14	6.68–15	1.21–15	1.82–16	1.99–17	1.34–18
$9h_{11/2}$	2.98–11	1.68–11	9.43–12	5.29–12	2.95–12	1.61–12	8.36–13	3.80–13	1.37–13	3.71–14	7.94–15	1.43–15	2.16–16	2.36–17	1.59–18
$9i_{11/2}$	1.89–11	1.06–11	5.97–12	3.34–12	1.86–12	1.00–12	4.98–13	2.09–13	6.73–14	1.64–14	3.29–15	5.77–16	8.60–17	9.35–18	6.28–19
$9i_{13/2}$	2.19–11	1.23–11	6.93–12	3.88–12	2.15–12	1.16–12	5.78–13	2.43–13	7.80–14	1.90–14	3.81–15	6.68–16	9.96–17	1.08–17	7.27–19
$10s_{1/2}$	3.60–12	2.03–12	1.14–12	6.42–13	3.61–13	2.03–13	1.14–13	6.32–14	3.45–14	1.83–14	9.12–15	4.04–15	1.39–15	3.14–16	4.52–17
$10p_{1/2}$	4.14–12	2.33–12	1.31–12	7.38–13	4.15–13	2.33–13	1.31–13	7.30–14	3.99–14	2.07–14	9.47–15	3.50–15	9.41–16	1.62–16	1.71–17
$10p_{3/2}$	9.96–12	5.61–12	3.16–12	1.78–12	9.98–13	5.60–13	3.12–13	1.71–13	8.97–14	4.37–14	1.84–14	6.19–15	1.51–15	2.33–16	2.14–17
$10d_{3/2}$	1.10–11	6.20–12	3.49–12	1.96–12	1.10–12	6.17–13	3.42–13	1.84–13	9.19–14	3.97–14	1.37–14	3.57–15	6.79–16	8.44–17	6.09–18
$10d_{5/2}$	1.61–11	9.07–12	5.10–12	2.87–12	1.61–12	9.02–13	4.99–13	2.67–13	1.33–13	5.66–14	1.91–14	4.90–15	9.15–16	1.12–16	8.06–18
$10f_{5/2}$	1.64–11	9.26–12	5.21–12	2.93–12	1.64–12	9.15–13	4.99–13	2.57–13	1.16–13	4.22–14	1.17–14	2.49–15	4.08–16	4.62–17	3.23–18
$10f_{7/2}$	2.17–11	1.22–11	6.86–12	3.86–12	2.16–12	1.20–12	6.57–13	3.38–13	1.52–13	5.50–14	1.51–14	3.21–15	5.24–16	5.92–17	4.08–18
$10g_{7/2}$	2.05–11	1.15–11	6.49–12	3.64–12	2.04–12	1.13–12	6.01–13	2.93–13	1.18–13	3.67–14	8.70–15	1.67–15	2.57–16	2.83–17	1.91–18
$10g_{9/2}$	2.54–11	1.43–11	8.05–12	4.52–12	2.53–12	1.40–12	7.46–13	3.63–13	1.46–13	4.52–14	1.07–14	2.05–15	3.16–16	3.48–17	2.35–18
$10h_{9/2}$	2.17–11	1.22–11	6.86–12	3.85–12	2.15–12	1.17–12	6.07–13	2.76–13	9.92–14	2.69–14	5.76–15	1.04–15	1.57–16	1.72–17	1.15–18
$10h_{11/2}$	2.58–11	1.45–11	8.18–12	4.60–12	2.56–12	1.40–12	7.25–13	3.29–13	1.18–13	3.20–14	6.85–15	1.24–15	1.87–16	2.04–17	1.37–18
$10i_{11/2}$	1.87–11	1.05–11	5.93–12	3.32–12	1.84–12	9.94–13	4.95–13	2.08–13	6.68–14	1.63–14	3.26–15	5.72–16	8.52–17	9.27–18	6.22–19
$10i_{13/2}$	2.17–11	1.22–11	6.89–12	3.86–12	2.14–12	1.15–12	5.75–13	2.41–13	7.74–14	1.89–14	3.78–15	6.62–16	9.87–17	1.07–17	7.21–19
$11s_{1/2}$	2.80–12	1.58–12	8.88–13	5.00–13	2.81–13	1.58–13	8.82–14	4.88–14	2.64–14	1.38–14	6.87–15	3.03–15	1.04–15	2.35–16	3.37–17
$11p_{1/2}$	3.20–12	1.80–12	1.01–12	5.70–13	3.21–13	1.80–13	1.01–13	5.61–14	3.04–14	1.56–14	7.13–15	2.63–15	7.07–16	1.21–16	1.28–17
$11p_{3/2}$	7.77–12	4.37–12	2.46–12	1.39–12	7.79–13	4.36–13	2.42–13	1.32–13	6.89–14	3.32–14	1.39–14	4.67–15	1.13–15	1.75–16	1.60–17
$11d_{3/2}$	8.59–12	4.83–12	2.72–12	1.53–12	8.60–13	4.81–13	2.66–13	1.42–13	7.07–14	3.04–14	1.04–14	2.72–15	5.16–16	6.40–17	4.59–18
$11d_{5/2}$	1.26–11	7.08–12	3.99–12	2.24–12	1.26–12	7.04–13	3.89–13	2.07–13	1.02–13	4.33–14	1.46–14	3.73–15	6.96–16	8.52–17	6.06–18
$11f_{5/2}$	1.30–11	7.30–12	4.11–12	2.31–12	1.30–12	7.22–13	3.93–13	2.02–13	9.09–14	3.28–14	9.06–15	1.93–15	3.17–16	3.57–17	2.43–18
$11f_{7/2}$	1.71–11	9.63–12	5.42–12	3.05–12	1.71–12	9.52–13	5.18–13	2.65–13	1.19–13	4.28–14	1.18–14	2.49–15	4.07–16	4.59–17	3.13–18
$11g_{7/2}$	1.66–11	9.33–12	5.25–12	2.95–12	1.65–12	9.13–13	4.86–13	2.36–13	9.53–14	2.95–14	6.98–15	1.33–15	2.06–16	2.27–17	1.53–18
$11g_{9/2}$	2.06–11	1.16–11	6.53–12	3.67–12	2.05–12	1.13–12	6.04–13	2.93–13	1.18–13	3.64–14	8.60–15	1.64–15	2.53–16	2.79–17	1.88–18
$11h_{9/2}$	1.84–11	1.04–11	5.84–12	3.28–12	1.83–12	1.00–12	5.17–13	2.35–13	8.43–14	2.28–14	4.88–15	8.83–16	1.33–16	1.45–17	9.77–19
$11h_{11/2}$	2.20–11	1.24–11	6.98–12	3.92–12	2.19–12	1.19–12	6.18–13	2.80–13	1.00–13	2.72–14	5.81–15	1.05–15	1.58–16	1.73–17	1.16–18
$11i_{11/2}$	1.74–11	9.81–12	5.52–12	3.10–12	1.72–12	9.25–13	4.61–13	1.93–13	6.20–14	1.51–14	3.03–15	5.31–16	7.91–17	8.60–18	5.78–19
$11i_{13/2}$	2.03–11	1.14–11	6.42–12	3.60–12	2.00–12	1.08–12	5.36–13	2.24–13	7.20–14	1.75–14	3.51–15	6.15–16	9.17–17	9.97–18	6.69–19

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$12s_{1/2}$	2.23–12	1.26–12	7.07–13	3.98–13	2.24–13	1.26–13	7.00–14	3.85–14	2.07–14	1.07–14	5.30–15	2.33–15	7.98–16	1.80–16	2.59–17
$12p_{1/2}$	2.53–12	1.42–12	8.02–13	4.52–13	2.54–13	1.43–13	7.97–14	4.40–14	2.37–14	1.21–14	5.50–15	2.02–15	5.42–16	9.30–17	9.81–18
$12p_{3/2}$	6.20–12	3.49–12	1.97–12	1.11–12	6.21–13	3.48–13	1.93–13	1.04–13	5.40–14	2.59–14	1.08–14	3.61–15	8.75–16	1.35–16	1.24–17
$12d_{3/2}$	6.84–12	3.85–12	2.17–12	1.22–12	6.85–13	3.83–13	2.11–13	1.13–13	5.56–14	2.37–14	8.12–15	2.11–15	4.00–16	4.96–17	3.53–18
$12d_{5/2}$	1.00–11	5.65–12	3.18–12	1.79–12	1.01–12	5.61–13	3.09–13	1.64–13	8.04–14	3.39–14	1.14–14	2.90–15	5.41–16	6.63–17	4.72–18
$12f_{5/2}$	1.04–11	5.87–12	3.30–12	1.86–12	1.04–12	5.79–13	3.15–13	1.61–13	7.22–14	2.60–14	7.16–15	1.52–15	2.49–16	2.80–17	1.90–18
$12f_{7/2}$	1.38–11	7.75–12	4.36–12	2.45–12	1.38–12	7.65–13	4.15–13	2.12–13	9.47–14	3.39–14	9.29–15	1.97–15	3.21–16	3.63–17	2.46–18
$12g_{7/2}$	1.36–11	7.63–12	4.30–12	2.42–12	1.35–12	7.46–13	3.97–13	1.92–13	7.74–14	2.39–14	5.65–15	1.08–15	1.67–16	1.83–17	1.24–18
$12g_{9/2}$	1.69–11	9.49–12	5.34–12	3.00–12	1.68–12	9.27–13	4.93–13	2.39–13	9.58–14	2.95–14	6.96–15	1.33–15	2.05–16	2.26–17	1.52–18
$12h_{9/2}$	1.56–11	8.80–12	4.95–12	2.78–12	1.55–12	8.48–13	4.38–13	1.98–13	7.11–14	1.92–14	4.11–15	7.43–16	1.12–16	1.22–17	8.22–19
$12h_{11/2}$	1.87–11	1.05–11	5.92–12	3.33–12	1.85–12	1.01–12	5.23–13	2.37–13	8.48–14	2.29–14	4.89–15	8.84–16	1.33–16	1.45–17	9.78–19
$12i_{11/2}$	1.57–11	8.84–12	4.98–12	2.79–12	1.55–12	8.34–13	4.15–13	1.74–13	5.58–14	1.36–14	2.72–15	4.77–16	7.10–17	7.72–18	5.19–19
$12i_{13/2}$	1.83–11	1.03–11	5.79–12	3.25–12	1.80–12	9.70–13	4.83–13	2.02–13	6.47–14	1.58–14	3.15–15	5.53–16	8.23–17	8.95–18	6.01–19
total	5.51–09	3.10–09	1.74–09	9.79–10	5.46–10	3.00–10	1.59–10	7.89–11	3.60–11	1.48–11	5.35–12	1.65–12	4.05–13	6.86–14	7.59–15
W^{70+}															
$2p_{1/2}$	4.82–10	2.71–10	1.52–10	8.57–11	4.82–11	2.71–11	1.52–11	8.47–12	4.64–12	2.42–12	1.13–12	4.29–13	1.18–13	2.08–14	2.24–15
$2p_{3/2}$	7.71–10	4.34–10	2.44–10	1.37–10	7.71–11	4.33–11	2.43–11	1.35–11	7.35–12	3.77–12	1.70–12	6.06–13	1.55–13	2.48–14	2.36–15
$3s_{1/2}$	1.21–10	6.80–11	3.82–11	2.15–11	1.21–11	6.80–12	3.83–12	2.15–12	1.21–12	6.79–13	3.64–13	1.72–13	6.17–14	1.43–14	2.11–15
$3p_{1/2}$	1.52–10	8.57–11	4.82–11	2.71–11	1.52–11	8.56–12	4.81–12	2.69–12	1.48–12	7.86–13	3.72–13	1.42–13	3.94–14	6.90–15	7.41–16
$3p_{3/2}$	2.82–10	1.59–10	8.92–11	5.02–11	2.82–11	1.58–11	8.88–12	4.95–12	2.70–12	1.39–12	6.24–13	2.22–13	5.62–14	8.92–15	8.41–16
$3d_{3/2}$	2.10–10	1.18–10	6.66–11	3.74–11	2.10–11	1.18–11	6.56–12	3.58–12	1.84–12	8.34–13	3.03–13	8.27–14	1.62–14	2.04–15	1.50–16
$3d_{5/2}$	2.91–10	1.64–10	9.20–11	5.17–11	2.91–11	1.63–11	9.06–12	4.93–12	2.53–12	1.14–12	4.06–13	1.09–13	2.10–14	2.61–15	1.90–16
$4s_{1/2}$	5.40–11	3.04–11	1.71–11	9.61–12	5.40–12	3.04–12	1.71–12	9.64–13	5.43–13	3.03–13	1.60–13	7.42–14	2.62–14	6.01–15	8.75–16
$4p_{1/2}$	6.66–11	3.75–11	2.11–11	1.18–11	6.66–12	3.75–12	2.10–12	1.18–12	6.54–13	3.47–13	1.65–13	6.26–14	1.72–14	3.00–15	3.21–16
$4p_{3/2}$	1.34–10	7.51–11	4.23–11	2.38–11	1.34–11	7.50–12	4.21–12	2.34–12	1.28–12	6.54–13	2.92–13	1.02–13	2.57–14	4.04–15	3.78–16
$4d_{3/2}$	1.26–10	7.08–11	3.98–11	2.24–11	1.26–11	7.05–12	3.93–12	2.14–12	1.11–12	5.01–13	1.82–13	4.96–14	9.68–15	1.22–15	8.96–17
$4d_{5/2}$	1.78–10	9.99–11	5.62–11	3.16–11	1.77–11	9.95–12	5.54–12	3.02–12	1.55–12	6.95–13	2.48–13	6.63–14	1.27–14	1.58–15	1.15–16
$4f_{5/2}$	9.75–11	5.48–11	3.08–11	1.73–11	9.73–12	5.43–12	2.98–12	1.57–12	7.37–13	2.83–13	8.24–14	1.82–14	3.05–15	3.48–16	2.38–17
$4f_{7/2}$	1.26–10	7.06–11	3.97–11	2.23–11	1.25–11	6.99–12	3.84–12	2.01–12	9.45–13	3.61–13	1.05–13	2.31–14	3.84–15	4.37–16	2.99–17
$5s_{1/2}$	2.92–11	1.64–11	9.25–12	5.20–12	2.92–12	1.65–12	9.26–13	5.21–13	2.93–13	1.62–13	8.47–14	3.85–14	1.34–14	3.06–15	4.42–16
$5p_{1/2}$	3.52–11	1.98–11	1.11–11	6.27–12	3.52–12	1.98–12	1.11–12	6.25–13	3.47–13	1.84–13	8.67–14	3.28–14	8.95–15	1.56–15	1.66–16
$5p_{3/2}$	7.43–11	4.18–11	2.35–11	1.32–11	7.43–12	4.18–12	2.34–12	1.30–12	7.08–13	3.60–13	1.58–13	5.51–14	1.37–14	2.14–15	2.00–16
$5d_{3/2}$	7.56–11	4.25–11	2.39–11	1.35–11	7.56–12	4.24–12	2.36–12	1.29–12	6.64–13	3.00–13	1.08–13	2.94–14	5.73–15	7.21–16	5.28–17
$5d_{5/2}$	1.08–10	6.08–11	3.42–11	1.92–11	1.08–11	6.05–12	3.37–12	1.83–12	9.39–13	4.20–13	1.49–13	3.97–14	7.59–15	9.42–16	6.84–17
$5f_{5/2}$	8.39–11	4.72–11	2.65–11	1.49–11	8.37–12	4.67–12	2.57–12	1.35–12	6.35–13	2.43–13	7.09–14	1.57–14	2.62–15	2.99–16	2.04–17
$5f_{7/2}$	1.09–10	6.12–11	3.44–11	1.93–11	1.08–11	6.06–12	3.33–12	1.75–12	8.19–13	3.13–13	9.06–14	1.99–14	3.32–15	3.77–16	2.58–17
$5g_{7/2}$	4.77–11	2.68–11	1.51–11	8.48–12	4.75–12	2.63–12	1.42–12	7.08–13	2.99–13	9.77–14	2.42–14	4.75–15	7.42–16	8.20–17	5.54–18
$5g_{9/2}$	5.85–11	3.29–11	1.85–11	1.04–11	5.82–12	3.23–12	1.74–12	8.66–13	3.65–13	1.19–13	2.94–14	5.77–15	9.01–16	9.96–17	6.73–18
$6s_{1/2}$	1.78–11	1.00–11	5.64–12	3.17–12	1.78–12	1.00–12	5.65–13	3.18–13	1.78–13	9.73–14	5.01–14	2.25–14	7.77–15	1.76–15	2.53–16
$6p_{1/2}$	2.11–11	1.19–11	6.67–12	3.75–12	2.11–12	1.19–12	6.67–13	3.74–13	2.07–13	1.09–13	5.12–14	1.92–14	5.22–15	9.04–16	9.60–17
$6p_{3/2}$	4.60–11	2.59–11	1.46–11	8.19–12	4.61–12	2.59–12	1.45–12	8.05–13	4.35–13	2.19–13	9.54–14	3.28–14	8.11–15	1.27–15	1.17–16
$6d_{3/2}$	4.83–11	2.72–11	1.53–11	8.60–12	4.83–12	2.71–12	1.51–12	8.23–13	4.23–13	1.90–13	6.83–14	1.84–14	3.58–15	4.50–16	3.29–17
$6d_{5/2}$	6.95–11	3.91–11	2.20–11	1.24–11	6.95–12	3.89–12	2.17–12	1.18–12	6.02–13	2.68–13	9.44–14	2.50–14	4.77–15	5.91–16	4.28–17
$6f_{5/2}$	6.20–11	3.48–11	1.96–11	1.10–11	6.18–12	3.45–12	1.90–12	9.96–13	4.68–13	1.79–13	5.20–14	1.15–14	1.92–15	2.18–16	1.49–17
$6f_{7/2}$	8.08–11	4.54–11	2.55–11	1.44–11	8.05–12	4.49–12	2.47–12	1.29–12	6.07–13	2.31–13	6.67–14	1.46–14	2.43–15	2.77–16	1.89–17
$6g_{7/2}$	5.34–11	3.00–11	1.69–11	9.49–12	5.31–12	2.95–12	1.59–12	7.92–13	3.35–13	1.09–13	2.70–14	5.30–15	8.29–16	9.16–17	6.19–18
$6g_{9/2}$	6.57–11	3.69–11	2.08–11	1.17–11	6.54–12	3.62–12	1.95–12	9.73–13	4.10–13	1.34–13	3.30–14	6.47–15	1.01–15	1.12–16	7.54–18
$6h_{9/2}$	2.39–11	1.34–11	7.56–12	4.24–12	2.37–12	1.30–12	6.82–13	3.19–13	1.20–13	3.42–14	7.56–15	1.39–15	2.11–16	2.30–17	1.55–18
$6h_{11/2}$	2.83–11	1.59–11	8.96–12	5.03–12	2.81–12	1.54–12	8.09–13	3.78–13	1.42–13	4.04–14	8.93–15	1.64–15	2.49–16	2.72–17	1.83–18
$7s_{1/2}$	1.18–11	6.64–12	3.73–12	2.10–12	1.18–12	6.64–13	3.73–13	2.09–13	1.16–13	6.30–14	3.20–14	1.42–14	4.89–15	1.10–15	1.58–16
$7p_{1/2}$	1.37–11	7.72–12	4.34–12	2.44–12	1.37–12	7.73–13	4.34–13	2.43–13	1.34–13	7.05–14	3.27–14	1.22–14	3.30–15	5.70–16	6.04–17
$7p_{3/2}$	3.08–11	1.73–11	9.74–12	5.47–12	3.08–12	1.73–12	9.67–13	5.36–13	2.88–13	1.43–13	6.18–14	2.11–14	5.19–15	8.07–16	7.47–17
$7d_{3/2}$	3.27–11	1.84–11	1.04–11	5.83–12	3.27–12	1.83–12	1.02–12	5.56–13	2.85–13	1.27–13	4.54–14	1.22–14	2.36–15	2.97–16	2.17–17
$7d_{5/2}$	4.73–11	2.66–11	1.50–11	8.42–12	4.73–12	2.65–12	1.47–12	8.00–13	4.07–13	1.80–13	6.30–14	1.66–14	3.16–15	3.91–16	2.83–17
$7f_{5/2}$	4.51–11	2.54–11	1.43–11	8.03–12	4.50–12	2.51–12	1.38–12	7.25–13	3.40–13	1.29–13	3.75–14	8.26–15	1.38–15	1.57–16	1.07–17
$7f_{7/2}$	5.90–11	3.32–11	1.87–11	1.05–11	5.89–12	3.29–12	1.80–12	9.45–13	4.42–13	1.68–13	4.83–14	1.06–14	1.76–15	2.00–16	1.36–17
$7g_{7/2}$	4.66–11	2.62–11	1.47–11	8.28–12	4.64–12	2.57–12	1.39–12	6.91–13	2.92–13	9.50–14	2.35–14	4.60–15	7.19–16	7.95–17	5.37–18
$7g_{9/2}$	5.75–11	3.23–11	1.82–11	1.02–11	5.72–12	3.17–12	1.71–12	8.51–13	3.58–13	1.17–13	2.87–14	5.62–15	8.78–16	9.70–17	6.55–18
$7h_{9/2}$	3.30–11	1.85–11	1.04–11	5.85–12	3.27–12	1.79–12	9.42–13	4.41–13	1.66–13	4.72–14	1.04–14	1.91–15	2.90–16	3.18–17	2.14–18
$7h_{11/2}$	3.91–11	2.20–11	1.24–11	6.95–12	3.88–12	2.13–12	1.12–12	5.23–13	1.97–13	5.58–14	1.23–14	2.26–15	3.43–16	3.75–17	2.53–18
$7i_{11/2}$	1.21–11	6.80–12	3.82–12	2.14–12	1.19–12	6.47–13	3.28–13	1.43–13	4.81–14	1.22–14	2.50–15	4.43–16	6.63–17	7.21–18	4.85–19
$7i_{13/2}$	1.40–11	7.87–12	4.42–12	2.48–12	1.38–12	7.49–13	3.80–13	1.65–13	5.55–14	1.41–14	2.89–15	5.11–16	7.65–17	8.32–18	5.59–19
$8s_{1/2}$	8.28–12	4.66–12	2.62–12	1.47–12	8.29–13	4.66–13	2.62–13	1.46–13	8.08–14	4.32–14	2.17–14	9.57–15	3.27–15	7.35–16	1.05–16
$8p_{1/2}$	9.51–12	5.35–12	3.01–12	1.69–12	9.52–13	5.35–13	3.01–13	1.68–13	9.24–14	4.81–14	2.21–14	8.21–15	2.22–15	3.82–16	4.05–17
$8p_{3/2}$	2.17–11	1.22–11	6.88–12	3.87–12	2.18–12	1.22–12	6.82–13	3.76–13	2.01–13	9.90–14	4.23–14	1.44–14	3.51–15	5.45–16	5.04–17

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$8d_{3/2}$	2.32–11	1.31–11	7.35–12	4.14–12	2.32–12	1.30–12	7.24–13	3.93–13	2.00–13	8.90–14	3.16–14	8.46–15	1.64–15	2.05–16	1.50–17
$8d_{5/2}$	3.37–11	1.90–11	1.07–11	6.00–12	3.37–12	1.89–12	1.05–12	5.68–13	2.87–13	1.26–13	4.40–14	1.15–14	2.19–15	2.71–16	1.96–17
$8f_{5/2}$	3.34–11	1.88–11	1.06–11	5.94–12	3.33–12	1.86–12	1.02–12	5.35–13	2.50–13	9.50–14	2.74–14	6.03–15	1.00–15	1.14–16	7.82–18
$8f_{7/2}$	4.38–11	2.46–11	1.39–11	7.79–12	4.37–12	2.44–12	1.34–12	7.00–13	3.26–13	1.23–13	3.53–14	7.73–15	1.28–15	1.46–16	9.95–18
$8g_{7/2}$	3.80–11	2.14–11	1.20–11	6.76–12	3.79–12	2.10–12	1.13–12	5.64–13	2.37–13	7.72–14	1.91–14	3.73–15	5.83–16	6.44–17	4.35–18
$8g_{9/2}$	4.70–11	2.65–11	1.49–11	8.36–12	4.68–12	2.59–12	1.40–12	6.95–13	2.92–13	9.49–14	2.34–14	4.56–15	7.12–16	7.87–17	5.32–18
$8h_{9/2}$	3.32–11	1.86–11	1.05–11	5.89–12	3.29–12	1.81–12	9.48–13	4.43–13	1.67–13	4.74–14	1.05–14	1.92–15	2.91–16	3.19–17	2.14–18
$8h_{11/2}$	3.95–11	2.22–11	1.25–11	7.01–12	3.91–12	2.15–12	1.13–12	5.27–13	1.98–13	5.62–14	1.24–14	2.27–15	3.45–16	3.77–17	2.54–18
$8i_{11/2}$	1.99–11	1.12–11	6.28–12	3.52–12	1.96–12	1.06–12	5.39–13	2.34–13	7.89–14	2.00–14	4.11–15	7.27–16	1.09–16	1.18–17	7.96–19
$8i_{13/2}$	2.30–11	1.29–11	7.28–12	4.08–12	2.27–12	1.23–12	6.24–13	2.71–13	9.13–14	2.32–14	4.75–15	8.40–16	1.26–16	1.37–17	9.19–19
$9s_{1/2}$	6.07–12	3.42–12	1.92–12	1.08–12	6.09–13	3.42–13	1.92–13	1.07–13	5.85–14	3.09–14	1.54–14	6.74–15	2.29–15	5.14–16	7.37–17
$9p_{1/2}$	6.90–12	3.88–12	2.18–12	1.23–12	6.92–13	3.89–13	2.18–13	1.22–13	6.64–14	3.43–14	1.57–14	5.79–15	1.56–15	2.68–16	2.83–17
$9p_{3/2}$	1.60–11	9.01–12	5.07–12	2.85–12	1.60–12	8.99–13	5.02–13	2.76–13	1.46–13	7.13–14	3.02–14	1.02–14	2.49–15	3.85–16	3.56–17
$9d_{3/2}$	1.71–11	9.65–12	5.43–12	3.05–12	1.72–12	9.61–13	5.34–13	2.89–13	1.46–13	6.46–14	2.28–14	6.09–15	1.17–15	1.47–16	1.07–17
$9d_{5/2}$	2.49–11	1.40–11	7.89–12	4.44–12	2.49–12	1.40–12	7.75–13	4.18–13	2.10–13	9.17–14	3.18–14	8.32–15	1.58–15	1.95–16	1.41–17
$9f_{5/2}$	2.53–11	1.42–11	8.00–12	4.50–12	2.52–12	1.41–12	7.72–13	4.04–13	1.88–13	7.11–14	2.05–14	4.49–15	7.47–16	8.51–17	5.82–18
$9f_{7/2}$	3.32–11	1.87–11	1.05–11	5.91–12	3.32–12	1.85–12	1.01–12	5.29–13	2.46–13	9.23–14	2.64–14	5.76–15	9.55–16	1.09–16	7.42–18
$9g_{7/2}$	3.06–11	1.72–11	9.67–12	5.43–12	3.04–12	1.69–12	9.08–13	4.52–13	1.90–13	6.16–14	1.52–14	2.97–15	4.64–16	5.12–17	3.46–18
$9g_{9/2}$	3.78–11	2.13–11	1.20–11	6.73–12	3.77–12	2.09–12	1.12–12	5.58–13	2.34–13	7.58–14	1.86–14	3.64–15	5.67–16	6.27–17	4.23–18
$9h_{9/2}$	3.00–11	1.69–11	9.49–12	5.33–12	2.98–12	1.63–12	8.57–13	4.01–13	1.51–13	4.27–14	9.42–15	1.73–15	2.62–16	2.87–17	1.93–18
$9h_{11/2}$	3.57–11	2.01–11	1.13–11	6.35–12	3.54–12	1.95–12	1.02–12	4.76–13	1.79–13	5.07–14	1.12–14	2.05–15	3.11–16	3.40–17	2.29–18
$9i_{11/2}$	2.26–11	1.27–11	7.16–12	4.02–12	2.23–12	1.21–12	6.15–13	2.67–13	8.99–14	2.28–14	4.68–15	8.28–16	1.24–16	1.35–17	9.06–19
$9i_{13/2}$	2.63–11	1.48–11	8.31–12	4.66–12	2.59–12	1.41–12	7.13–13	3.10–13	1.04–13	2.64–14	5.41–15	9.57–16	1.43–16	1.56–17	1.05–18
$10s_{1/2}$	4.61–12	2.60–12	1.46–12	8.21–13	4.62–13	2.59–13	1.45–13	8.05–14	4.37–14	2.29–14	1.13–14	4.92–15	1.67–15	3.74–16	5.34–17
$10p_{1/2}$	5.20–12	2.92–12	1.65–12	9.26–13	5.20–13	2.92–13	1.64–13	9.10–14	4.94–14	2.53–14	1.15–14	4.23–15	1.14–15	1.96–16	2.07–17
$10p_{3/2}$	1.22–11	6.87–12	3.87–12	2.17–12	1.22–12	6.85–13	3.81–13	2.08–13	1.09–13	5.30–14	2.23–14	7.49–15	1.82–15	2.82–16	2.60–17
$10d_{3/2}$	1.31–11	7.35–12	4.14–12	2.33–12	1.31–12	7.31–13	4.06–13	2.19–13	1.10–13	4.83–14	1.70–14	4.52–15	8.70–16	1.09–16	7.84–18
$10d_{5/2}$	1.90–11	1.07–11	6.03–12	3.39–12	1.90–12	1.07–12	5.90–13	3.17–13	1.59–13	6.87–14	2.37–14	6.18–15	1.17–15	1.44–16	1.03–17
$10f_{5/2}$	1.95–11	1.10–11	6.19–12	3.48–12	1.95–12	1.09–12	5.96–13	3.11–13	1.44–13	5.43–14	1.56–14	3.42–15	5.68–16	6.46–17	4.42–18
$10f_{7/2}$	2.57–11	1.45–11	8.14–12	4.58–12	2.57–12	1.43–12	7.84–13	4.08–13	1.89–13	7.06–14	2.01–14	4.39–15	7.27–16	8.26–17	5.66–18
$10g_{7/2}$	2.46–11	1.38–11	7.78–12	4.37–12	2.45–12	1.36–12	7.29–13	3.62–13	1.52–13	4.92–14	1.21–14	2.36–15	3.69–16	4.08–17	2.75–18
$10g_{9/2}$	3.04–11	1.71–11	9.64–12	5.41–12	3.03–12	1.68–12	9.03–13	4.48–13	1.87–13	6.05–14	1.48–14	2.90–15	4.52–16	4.99–17	3.37–18
$10h_{9/2}$	2.60–11	1.46–11	8.23–12	4.62–12	2.58–12	1.42–12	7.43–13	3.47–13	1.30–13	3.68–14	8.12–15	1.49–15	2.26–16	2.47–17	1.66–18
$10h_{11/2}$	3.10–11	1.74–11	9.81–12	5.51–12	3.07–12	1.69–12	8.85–13	4.13–13	1.55–13	4.37–14	9.64–15	1.77–15	2.68–16	2.93–17	1.97–18
$10i_{11/2}$	2.25–11	1.26–11	7.11–12	3.99–12	2.22–12	1.20–12	6.10–13	2.65–13	8.92–14	2.26–14	4.63–15	8.20–16	1.23–16	1.33–17	8.97–19
$10i_{13/2}$	2.61–11	1.47–11	8.26–12	4.63–12	2.57–12	1.40–12	7.08–13	3.07–13	1.03–13	2.62–14	5.36–15	9.48–16	1.42–16	1.54–17	1.04–18
$11s_{1/2}$	3.59–12	2.02–12	1.14–12	6.41–13	3.60–13	2.02–13	1.13–13	6.23–14	3.36–14	1.74–14	8.53–15	3.70–15	1.25–15	2.80–16	4.00–17
$11p_{1/2}$	4.02–12	2.26–12	1.27–12	7.18–13	4.03–13	2.26–13	1.27–13	7.01–14	3.78–14	1.92–14	8.68–15	3.18–15	8.54–16	1.47–16	1.55–17
$11p_{3/2}$	9.54–12	5.37–12	3.02–12	1.70–12	9.56–13	5.35–13	2.97–13	1.62–13	8.42–14	4.05–14	1.69–14	5.66–15	1.37–15	2.12–16	1.96–17
$11d_{3/2}$	1.02–11	5.74–12	3.23–12	1.82–12	1.02–12	5.71–13	3.16–13	1.70–13	8.50–14	3.71–14	1.30–14	3.44–15	6.62–16	8.27–17	5.94–18
$11d_{5/2}$	1.49–11	8.38–12	4.72–12	2.65–12	1.49–12	8.33–13	4.60–13	2.47–13	1.23–13	5.27–14	1.81–14	4.72–15	8.91–16	1.10–16	7.76–18
$11f_{5/2}$	1.54–11	8.67–12	4.88–12	2.75–12	1.54–12	8.59–13	4.70–13	2.44–13	1.13–13	4.23–14	1.21–14	2.65–15	4.41–16	5.03–17	3.38–18
$11f_{7/2}$	2.03–11	1.14–11	6.43–12	3.62–12	2.03–12	1.13–12	6.18–13	3.21–13	1.48–13	5.50–14	1.57–14	3.41–15	5.64–16	6.40–17	4.37–18
$11g_{7/2}$	1.99–11	1.12–11	6.29–12	3.54–12	1.98–12	1.10–12	5.90–13	2.92–13	1.22–13	3.95–14	9.69–15	1.89–15	2.95–16	3.26–17	2.20–18
$11g_{9/2}$	2.47–11	1.39–11	7.81–12	4.39–12	2.46–12	1.36–12	7.31–13	3.62–13	1.51–13	4.86–14	1.19–14	2.32–15	3.62–16	4.00–17	2.70–18
$11h_{9/2}$	2.21–11	1.25–11	7.01–12	3.94–12	2.20–12	1.21–12	6.32–13	2.95–13	1.10–13	3.12–14	6.88–15	1.26–15	1.91–16	2.09–17	1.41–18
$11h_{11/2}$	2.64–11	1.49–11	8.36–12	4.70–12	2.62–12	1.44–12	7.54–13	3.51–13	1.31–13	3.71–14	8.17–15	1.50–15	2.27–16	2.48–17	1.67–18
$11i_{11/2}$	2.09–11	1.18–11	6.62–12	3.72–12	2.07–12	1.12–12	5.68–13	2.47–13	8.28–14	2.10–14	4.30–15	7.60–16	1.14–16	1.24–17	8.31–19
$11i_{13/2}$	2.43–11	1.37–11	7.69–12	4.32–12	2.40–12	1.30–12	6.60–13	2.86–13	9.60–14	2.43–14	4.97–15	8.80–16	1.32–16	1.43–17	9.62–19
$12s_{1/2}$	2.87–12	1.62–12	9.09–13	5.12–13	2.88–13	1.61–13	8.98–14	4.93–14	2.64–14	1.36–14	6.60–15	2.85–15	9.62–16	2.15–16	3.07–17
$12p_{1/2}$	3.19–12	1.80–12	1.01–12	5.69–13	3.20–13	1.79–13	1.00–13	5.52–14	2.96–14	1.49–14	6.71–15	2.45–15	6.57–16	1.13–16	1.19–17
$12p_{3/2}$	7.64–12	4.30–12	2.42–12	1.36–12	7.65–13	4.28–13	2.37–13	1.28–13	6.62–14	3.16–14	1.31–14	4.38–15	1.06–15	1.64–16	1.51–17
$12d_{3/2}$	8.15–12	4.58–12	2.58–12	1.45–12	8.15–13	4.56–13	2.51–13	1.35–13	6.69–14	2.90–14	1.01–14	2.68–15	5.15–16	6.41–17	4.58–18
$12d_{5/2}$	1.19–11	6.70–12	3.77–12	2.12–12	1.19–12	6.65–13	3.67–13	1.96–13	9.66–14	4.13–14	1.41–14	3.67–15	6.93–16	8.61–17	6.03–18
$12f_{5/2}$	1.24–11	6.97–12	3.92–12	2.21–12	1.24–12	6.89–13	3.76–13	1.95–13	8.97–14	3.35–14	9.57–15	2.09–15	3.46–16	3.93–17	2.68–18
$12f_{7/2}$	1.63–11	9.19–12	5.18–12	2.91–12	1.63–12	9.09–13	4.96–13	2.56–13	1.18–13	4.36–14	1.24–14	2.69–15	4.46–16	5.10–17	3.41–18
$12g_{7/2}$	1.63–11	9.15–12	5.15–12	2.89–12	1.62–12	8.98–13	4.82–13	2.38–13	9.93–14	3.20–14	7.84–15	1.53–15	2.39–16	2.64–17	1.78–18
$12g_{9/2}$	2.02–11	1.14–11	6.39–12	3.60–12	2.01–12	1.11–12	5.98–13	2.95–13	1.23–13	3.94–14	9.64–15	1.88–15	2.93–16	3.23–17	2.18–18
$12h_{9/2}$	1.88–11	1.06–11	5.94–12	3.34–12	1.86–12	1.02–12	5.36–13	2.49–13	9.32–14	2.63–14	5.79–15	1.06–15	1.61–16	1.76–17	1.18–18
$12h_{11/2}$	2.24–11	1.26–11	7.10–12	3.99–12	2.23–12	1.22–12	6.39–13	2.97–13	1.11–13	3.13–14	6.88–15	1.26–15	1.91–16	2.09–17	1.41–18
$12i_{11/2}$	1.88–11	1.06–11	5.97–12	3.35–12	1.86–12	1.01–12	5.12–13	2.22–13	7.45–14	1.89–14	3.86–15	6.82–16	1.02–16	1.11–17	7.46–19
$12i_{13/2}$	2.19–11	1.23–11	6.94–12	3.89–12	2.17–12	1.17–12	5.95–13	2.58–13	8.64–14	2.19–14	4.47–15	7.90–16	1.18–16	1.29–17	8.64–19
total	7.75–09	4.36–09	2.45–09	1.38–09	7.70–10	4.25–10	2.29–10	1.17–10	5.57–11	2.42–11	9.34–12	3.04–12	7.59–13	1.27–13	1.35–14
$\boldsymbol{W^{72+}}$															
$2s_{1/2}$	3.98–10	2.24–10	1.26–10	7.08–11	3.98–11	2.24–11	1.26–11	7.07–12	3.97–12	2.21–12	1.18–12	5.64–13	2.07–13	4.94–14	7.45–15

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T\,(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$2p_{1/2}$	4.82–10	2.71–10	1.52–10	8.57–11	4.82–11	2.71–11	1.52–11	8.47–12	4.64–12	2.43–12	1.14–12	4.32–13	1.20–13	2.11–14	2.29–15
$2p_{3/2}$	7.68–10	4.32–10	2.43–10	1.37–10	7.68–11	4.32–11	2.42–11	1.35–11	7.33–12	3.77–12	1.70–12	6.09–13	1.56–13	2.51–14	2.40–15
$3s_{1/2}$	1.28–10	7.19–11	4.04–11	2.27–11	1.28–11	7.19–12	4.05–12	2.28–12	1.28–12	7.14–13	3.82–13	1.79–13	6.42–14	1.49–14	2.20–15
$3p_{1/2}$	1.58–10	8.89–11	5.00–11	2.81–11	1.58–11	8.88–12	4.99–12	2.79–12	1.54–12	8.13–13	3.85–13	1.47–13	4.08–14	7.17–15	7.73–16
$3p_{3/2}$	2.91–10	1.64–10	9.20–11	5.17–11	2.91–11	1.63–11	9.16–12	5.10–12	2.78–12	1.43–12	6.45–13	2.29–13	5.82–14	9.27–15	8.76–16
$3d_{3/2}$	2.16–10	1.21–10	6.82–11	3.84–11	2.16–11	1.21–11	6.73–12	3.67–12	1.90–12	8.63–13	3.16–13	8.68–14	1.71–14	2.16–15	1.59–16
$3d_{5/2}$	2.98–10	1.68–10	9.42–11	5.30–11	2.98–11	1.67–11	9.28–12	5.06–12	2.60–12	1.17–12	4.23–13	1.14–13	2.21–14	2.76–15	2.01–16
$4s_{1/2}$	5.76–11	3.24–11	1.82–11	1.02–11	5.76–12	3.24–12	1.82–12	1.03–12	5.78–13	3.21–13	1.69–13	7.80–14	2.75–14	6.30–15	9.16–16
$4p_{1/2}$	7.00–11	3.93–11	2.21–11	1.24–11	7.00–12	3.93–12	2.21–12	1.24–12	6.85–13	3.64–13	1.72–13	6.54–14	1.80–14	3.15–15	3.37–16
$4p_{3/2}$	1.39–10	7.84–11	4.41–11	2.48–11	1.39–11	7.83–12	4.39–12	2.44–12	1.33–12	6.82–13	3.04–13	1.07–13	2.68–14	4.23–15	3.97–16
$4d_{3/2}$	1.31–10	7.35–11	4.13–11	2.32–11	1.31–11	7.32–12	4.08–12	2.23–12	1.15–12	5.24–13	1.92–13	5.25–14	1.03–14	1.30–15	9.59–17
$4d_{5/2}$	1.84–10	1.04–10	5.82–11	3.27–11	1.84–11	1.03–11	5.74–12	3.13–12	1.61–12	7.26–13	2.61–13	7.02–14	1.35–14	1.69–15	1.23–16
$4f_{5/2}$	1.03–10	5.78–11	3.25–11	1.83–11	1.03–11	5.72–12	3.15–12	1.66–12	7.86–13	3.05–13	9.00–14	2.01–14	3.37–15	3.86–16	2.64–17
$4f_{7/2}$	1.32–10	7.43–11	4.18–11	2.35–11	1.32–11	7.36–12	4.04–12	2.13–12	1.01–12	3.88–13	1.14–13	2.53–14	4.24–15	4.84–16	3.31–17
$5s_{1/2}$	3.13–11	1.76–11	9.91–12	5.57–12	3.14–12	1.76–12	9.92–13	5.58–13	3.13–13	1.73–13	8.98–14	4.07–14	1.41–14	3.21–15	4.65–16
$5p_{1/2}$	3.72–11	2.09–11	1.18–11	6.63–12	3.73–12	2.09–12	1.18–12	6.60–13	3.66–13	1.94–13	9.10–14	3.44–14	9.40–15	1.64–15	1.75–16
$5p_{3/2}$	7.81–11	4.39–11	2.47–11	1.39–11	7.81–12	4.39–12	2.46–12	1.37–12	7.42–13	3.77–13	1.66–13	5.78–14	1.44–14	2.26–15	2.10–16
$5d_{3/2}$	7.89–11	4.44–11	2.50–11	1.40–11	7.89–12	4.42–12	2.46–12	1.35–12	6.95–13	3.16–13	1.15–13	3.13–14	6.12–15	7.74–16	5.68–17
$5d_{5/2}$	1.13–10	6.33–11	3.56–11	2.00–11	1.12–11	6.30–12	3.51–12	1.91–12	9.82–13	4.41–13	1.58–13	4.22–14	8.11–15	1.01–15	7.34–17
$5f_{5/2}$	8.83–11	4.97–11	2.79–11	1.57–11	8.81–12	4.92–12	2.71–12	1.43–12	6.77–13	2.62–13	7.73–14	1.72–14	2.89–15	3.31–16	2.26–17
$5f_{7/2}$	1.14–10	6.44–11	3.62–11	2.03–11	1.14–11	6.37–12	3.51–12	1.85–12	8.72–13	3.36–13	9.86–14	2.19–14	3.66–15	4.17–16	2.86–17
$5g_{7/2}$	5.06–11	2.85–11	1.60–11	9.00–12	5.04–12	2.79–12	1.51–12	7.57–13	3.23–13	1.07–13	2.68–14	5.30–15	8.32–16	9.21–17	6.22–18
$5g_{9/2}$	6.20–11	3.49–11	1.96–11	1.10–11	6.17–12	3.42–12	1.85–12	9.26–13	3.95–13	1.30–13	3.26–14	6.44–15	1.01–15	1.12–16	7.55–18
$6s_{1/2}$	1.92–11	1.08–11	6.07–12	3.41–12	1.92–12	1.08–12	6.07–13	3.41–13	1.90–13	1.04–13	5.33–14	2.38–14	8.20–15	1.85–15	2.67–16
$6p_{1/2}$	2.24–11	1.26–11	7.08–12	3.98–12	2.24–12	1.26–12	7.07–13	3.96–13	2.19–13	1.16–13	5.39–14	2.02–14	5.50–15	9.54–16	1.01–16
$6p_{3/2}$	4.85–11	2.73–11	1.54–11	8.64–12	4.86–12	2.73–12	1.53–12	8.48–13	4.58–13	2.31–13	1.00–13	3.46–14	8.55–15	1.33–15	1.24–16
$6d_{3/2}$	5.06–11	2.85–11	1.60–11	9.01–12	5.06–12	2.84–12	1.58–12	8.62–13	4.44–13	2.01–13	7.25–14	1.97–14	3.84–15	4.84–16	3.55–17
$6d_{5/2}$	7.27–11	4.09–11	2.30–11	1.29–11	7.27–12	4.07–12	2.27–12	1.23–12	6.32–13	2.82–13	1.00–13	2.67–14	5.11–15	6.35–16	4.61–17
$6f_{5/2}$	6.53–11	3.67–11	2.06–11	1.16–11	6.51–12	3.64–12	2.00–12	1.05–12	4.99–13	1.93–13	5.67–14	1.26–14	2.12–15	2.42–16	1.66–17
$6f_{7/2}$	8.50–11	4.78–11	2.69–11	1.51–11	8.48–12	4.73–12	2.60–12	1.37–12	6.46–13	2.49–13	7.27–14	1.61–14	2.69–15	3.06–16	2.09–17
$6g_{7/2}$	5.66–11	3.18–11	1.79–11	1.01–11	5.63–12	3.12–12	1.69–12	8.46–13	3.61–13	1.20–13	3.00–14	5.92–15	9.28–16	1.03–16	6.95–18
$6g_{9/2}$	6.95–11	3.91–11	2.20–11	1.24–11	6.92–12	3.84–12	2.07–12	1.04–12	4.43–13	1.46–13	3.66–14	7.21–15	1.13–15	1.25–16	8.45–18
$6h_{9/2}$	2.53–11	1.43–11	8.02–12	4.50–12	2.51–12	1.38–12	7.28–13	3.43–13	1.31–13	3.78–14	8.43–15	1.56–15	2.37–16	2.59–17	1.74–18
$6h_{11/2}$	3.00–11	1.69–11	9.49–12	5.33–12	2.98–12	1.64–12	8.62–13	4.06–13	1.55–13	4.46–14	9.95–15	1.84–15	2.79–16	3.05–17	2.06–18
$7s_{1/2}$	1.27–11	7.16–12	4.03–12	2.26–12	1.27–12	7.16–13	4.02–13	2.25–13	1.25–13	6.75–14	3.42–14	1.51–14	5.17–15	1.16–15	1.67–16
$7p_{1/2}$	1.46–11	8.22–12	4.62–12	2.60–12	1.46–12	8.22–13	4.62–13	2.59–13	1.43–13	7.46–14	3.45–14	1.29–14	3.48–15	6.02–16	6.40–17
$7p_{3/2}$	3.25–11	1.83–11	1.03–11	5.79–12	3.25–12	1.83–12	1.02–12	5.66–13	3.04–13	1.51–13	6.52–14	2.23–14	5.48–15	8.53–16	7.91–17
$7d_{3/2}$	3.44–11	1.93–11	1.09–11	6.11–12	3.44–12	1.93–12	1.07–12	5.84–13	3.00–13	1.35–13	4.83–14	1.31–14	2.54–15	3.20–16	2.34–17
$7d_{5/2}$	4.96–11	2.79–11	1.57–11	8.82–12	4.96–12	2.78–12	1.54–12	8.39–13	4.28–13	1.90–13	6.70–14	1.77–14	3.39–15	4.21–16	3.05–17
$7f_{5/2}$	4.76–11	2.67–11	1.50–11	8.46–12	4.75–12	2.65–12	1.46–12	7.67–13	3.62–13	1.40–13	4.09–14	9.09–15	1.52–15	1.74–16	1.19–17
$7f_{7/2}$	6.22–11	3.50–11	1.97–11	1.11–11	6.20–12	3.46–12	1.90–12	1.00–12	4.71–13	1.80–13	5.26–14	1.16–14	1.94–15	2.21–16	1.51–17
$7g_{7/2}$	4.93–11	2.77–11	1.56–11	8.77–12	4.91–12	2.73–12	1.47–12	7.38–13	3.15–13	1.04–13	2.60–14	5.14–15	8.05–16	8.91–17	6.02–18
$7g_{9/2}$	6.08–11	3.42–11	1.92–11	1.08–11	6.05–12	3.36–12	1.81–12	9.09–13	3.87–13	1.28–13	3.18–14	6.27–15	9.81–16	1.09–16	7.34–18
$7h_{9/2}$	3.49–11	1.96–11	1.11–11	6.20–12	3.46–12	1.91–12	1.00–12	4.73–13	1.81–13	5.20–14	1.16–14	2.14–15	3.26–16	3.57–17	2.40–18
$7h_{11/2}$	4.15–11	2.33–11	1.31–11	7.36–12	4.11–12	2.26–12	1.19–12	5.61–13	2.14–13	6.16–14	1.37–14	2.53–15	3.85–16	4.21–17	2.84–18
$7i_{11/2}$	1.28–11	7.21–12	4.06–12	2.27–12	1.27–12	6.88–13	3.51–13	1.54–13	5.26–14	1.35–14	2.80–15	4.97–16	7.44–17	8.10–18	5.44–19
$7i_{13/2}$	1.48–11	8.35–12	4.69–12	2.63–12	1.46–12	7.96–13	4.05–13	1.78–13	6.08–14	1.56–14	3.23–15	5.73–16	8.58–17	9.35–18	6.28–19
$8s_{1/2}$	8.95–12	5.03–12	2.83–12	1.59–12	8.95–13	5.03–13	2.82–13	1.58–13	8.69–14	4.64–14	2.32–14	1.02–14	3.46–15	7.77–16	1.11–16
$8p_{1/2}$	1.01–11	5.71–12	3.21–12	1.81–12	1.02–12	5.71–13	3.20–13	1.79–13	9.82–14	5.10–14	2.34–14	8.68–15	2.34–15	4.04–16	4.29–17
$8p_{3/2}$	2.30–11	1.30–11	7.29–12	4.10–12	2.30–12	1.29–12	7.22–13	3.98–13	2.12–13	1.05–13	4.47–14	1.52–14	3.71–15	5.77–16	5.34–17
$8d_{3/2}$	2.45–11	1.38–11	7.74–12	4.35–12	2.44–12	1.37–12	7.62–13	4.14–13	2.11–13	9.43–14	3.36–14	9.06–15	1.76–15	2.21–16	1.63–17
$8d_{5/2}$	3.54–11	1.99–11	1.12–11	6.30–12	3.54–12	1.98–12	1.10–12	5.97–13	3.03–13	1.33–13	4.68–14	1.23–14	2.35–15	2.92–16	2.12–17
$8f_{5/2}$	3.52–11	1.98–11	1.11–11	6.27–12	3.52–12	1.96–12	1.08–12	5.67–13	2.67–13	1.02–13	2.99–14	6.63–15	1.11–15	1.27–16	8.67–18
$8f_{7/2}$	4.62–11	2.60–11	1.46–11	8.21–12	4.61–12	2.57–12	1.41–12	7.41–13	3.48–13	1.33–13	3.85–14	8.49–15	1.41–15	1.61–16	1.10–17
$8g_{7/2}$	4.03–11	2.27–11	1.27–11	7.16–12	4.01–12	2.23–12	1.20–12	6.02–13	2.56–13	8.45–14	2.11–14	4.16–15	6.52–16	7.22–17	4.88–18
$8g_{9/2}$	4.98–11	2.80–11	1.57–11	8.85–12	4.96–12	2.75–12	1.48–12	7.42–13	3.15–13	1.04–13	2.58–14	5.09–15	7.96–16	8.81–17	5.95–18
$8h_{9/2}$	3.51–11	1.98–11	1.11–11	6.24–12	3.49–12	1.92–12	1.01–12	4.76–13	1.81–13	5.23–14	1.17–14	2.15–15	3.27–16	3.58–17	2.41–18
$8h_{11/2}$	4.18–11	2.35–11	1.32–11	7.42–12	4.14–12	2.28–12	1.20–12	5.65–13	2.15–13	6.19–14	1.38–14	2.54–15	3.86–16	4.23–17	2.85–18
$8i_{11/2}$	2.10–11	1.18–11	6.66–12	3.73–12	2.08–12	1.13–12	5.76–13	2.53–13	8.64–14	2.22–14	4.59–15	8.15–16	1.22–16	1.33–17	8.93–19
$8i_{13/2}$	2.44–11	1.37–11	7.71–12	4.32–12	2.41–12	1.31–12	6.66–13	2.93–13	9.99–14	2.57–14	5.30–15	9.41–16	1.41–16	1.53–17	1.03–18
$9s_{1/2}$	6.57–12	3.69–12	2.08–12	1.17–12	6.58–13	3.69–13	2.07–13	1.15–13	6.30–14	3.33–14	1.65–14	7.17–15	2.43–15	5.44–16	7.78–17
$9p_{1/2}$	7.37–12	4.15–12	2.33–12	1.31–12	7.38–13	4.15–13	2.33–13	1.30–13	7.07–14	3.64–14	1.66–14	6.12–15	1.65–15	2.84–16	3.00–17
$9p_{3/2}$	1.70–11	9.57–12	5.38–12	3.03–12	1.70–12	9.54–13	5.32–13	2.92–13	1.54–13	7.55–14	3.19–14	1.08–14	2.63–15	4.08–16	3.77–17
$9d_{3/2}$	1.81–11	1.02–11	5.72–12	3.22–12	1.81–12	1.01–12	5.62–13	3.04–13	1.55–13	6.85–14	2.43–14	6.52–15	1.26–15	1.59–16	1.15–17
$9d_{5/2}$	2.62–11	1.48–11	8.30–12	4.67–12	2.62–12	1.47–12	8.15–13	4.40–13	2.22–13	9.71–14	3.39–14	8.91–15	1.69–15	2.10–16	1.51–17

Table 1 (*continued*)

Shell	$\log_{10}T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$9f_{5/2}$	2.66–11	1.50–11	8.43–12	4.74–12	2.66–12	1.48–12	8.15–13	4.28–13	2.01–13	7.67–14	2.23–14	4.94–15	8.26–16	9.42–17	6.45–18
$9f_{7/2}$	3.50–11	1.97–11	1.11–11	6.23–12	3.49–12	1.95–12	1.07–12	5.60–13	2.62–13	9.95–14	2.88–14	6.33–15	1.05–15	1.20–16	8.20–18
$9g_{7/2}$	3.23–11	1.82–11	1.02–11	5.75–12	3.22–12	1.79–12	9.64–13	4.83–13	2.05–13	6.75–14	1.68–14	3.31–15	5.19–16	5.74–17	3.88–18
$9g_{9/2}$	4.00–11	2.25–11	1.27–11	7.11–12	3.98–12	2.21–12	1.19–12	5.96–13	2.53–13	8.29–14	2.06–14	4.05–15	6.34–16	7.01–17	4.74–18
$9h_{9/2}$	3.18–11	1.79–11	1.01–11	5.65–12	3.15–12	1.73–12	9.13–13	4.30–13	1.64–13	4.71–14	1.05–14	1.94–15	2.94–16	3.22–17	2.17–18
$9h_{11/2}$	3.78–11	2.13–11	1.20–11	6.72–12	3.75–12	2.06–12	1.09–12	5.11–13	1.94–13	5.58–14	1.24–14	2.29–15	3.48–16	3.81–17	2.56–18
$9i_{11/2}$	2.40–11	1.35–11	7.59–12	4.26–12	2.37–12	1.29–12	6.56–13	2.88–13	9.84–14	2.53–14	5.22–15	9.27–16	1.39–16	1.51–17	1.02–18
$9i_{13/2}$	2.78–11	1.56–11	8.80–12	4.94–12	2.75–12	1.49–12	7.61–13	3.34–13	1.14–13	2.93–14	6.04–15	1.07–15	1.60–16	1.75–17	1.17–18
$10s_{1/2}$	4.99–12	2.81–12	1.58–12	8.89–13	5.00–13	2.81–13	1.57–13	8.70–14	4.72–14	2.47–14	1.21–14	5.24–15	1.77–15	3.95–16	5.65–17
$10p_{1/2}$	5.56–12	3.13–12	1.76–12	9.90–13	5.57–13	3.13–13	1.75–13	9.72–14	5.26–14	2.69–14	1.22–14	4.48–15	1.20–15	2.07–16	2.20–17
$10p_{3/2}$	1.30–11	7.30–12	4.11–12	2.31–12	1.30–12	7.28–13	4.05–13	2.21–13	1.16–13	5.62–14	2.36–14	7.93–15	1.93–15	2.99–16	2.76–17
$10d_{3/2}$	1.38–11	7.74–12	4.36–12	2.45–12	1.38–12	7.71–13	4.28–13	2.31–13	1.17–13	5.13–14	1.81–14	4.84–15	9.37–16	1.17–16	8.42–18
$10d_{5/2}$	2.00–11	1.13–11	6.35–12	3.57–12	2.00–12	1.12–12	6.21–13	3.34–13	1.68–13	7.28–14	2.53–14	6.63–15	1.26–15	1.56–16	1.12–17
$10f_{5/2}$	2.06–11	1.16–11	6.52–12	3.67–12	2.06–12	1.15–12	6.30–13	3.30–13	1.54–13	5.86–14	1.70–14	3.76–15	6.28–16	7.16–17	4.90–18
$10f_{7/2}$	2.71–11	1.52–11	8.58–12	4.82–12	2.71–12	1.51–12	8.28–13	4.32–13	2.01–13	7.61–14	2.20–14	4.82–15	8.02–16	9.13–17	6.25–18
$10g_{7/2}$	2.60–11	1.46–11	8.22–12	4.62–12	2.59–12	1.44–12	7.74–13	3.87–13	1.64–13	5.38–14	1.34–14	2.64–15	4.13–16	4.57–17	3.09–18
$10g_{9/2}$	3.22–11	1.81–11	1.02–11	5.73–12	3.21–12	1.78–12	9.58–13	4.78–13	2.02–13	6.62–14	1.64–14	3.23–15	5.05–16	5.58–17	3.77–18
$10h_{9/2}$	2.75–11	1.55–11	8.71–12	4.89–12	2.73–12	1.50–12	7.91–13	3.72–13	1.41–13	4.06–14	9.05–15	1.67–15	2.53–16	2.77–17	1.87–18
$10h_{11/2}$	3.28–11	1.85–11	1.04–11	5.83–12	3.26–12	1.79–12	9.42–13	4.43–13	1.68–13	4.82–14	1.07–14	1.98–15	3.00–16	3.28–17	2.21–18
$10i_{11/2}$	2.38–11	1.34–11	7.54–12	4.23–12	2.35–12	1.28–12	6.51–13	2.86–13	9.75–14	2.51–14	5.17–15	9.18–16	1.37–16	1.50–17	1.01–18
$10i_{13/2}$	2.76–11	1.55–11	8.74–12	4.90–12	2.73–12	1.48–12	7.55–13	3.31–13	1.13–13	2.90–14	5.98–15	1.06–15	1.59–16	1.73–17	1.16–18
$11s_{1/2}$	3.90–12	2.19–12	1.23–12	6.94–13	3.90–13	2.19–13	1.22–13	6.74–14	3.63–14	1.88–14	9.15–15	3.94–15	1.33–15	2.96–16	4.23–17
$11p_{1/2}$	4.31–12	2.42–12	1.36–12	7.67–13	4.32–13	2.42–13	1.35–13	7.49–14	4.03–14	2.05–14	9.21–15	3.37–15	9.04–16	1.55–16	1.65–17
$11p_{3/2}$	1.02–11	5.71–12	3.22–12	1.81–12	1.02–12	5.70–13	3.16–13	1.72–13	8.95–14	4.29–14	1.79–14	5.99–15	1.46–15	2.25–16	2.08–17
$11d_{3/2}$	1.08–11	6.06–12	3.41–12	1.92–12	1.08–12	6.03–13	3.34–13	1.79–13	9.00–14	3.93–14	1.38–14	3.69–15	7.12–16	8.90–17	6.39–18
$11d_{5/2}$	1.57–11	8.83–12	4.97–12	2.80–12	1.57–12	8.78–13	4.85–13	2.60–13	1.30–13	5.59–14	1.93–14	5.06–15	9.59–16	1.18–16	8.41–18
$11f_{5/2}$	1.63–11	9.15–12	5.15–12	2.90–12	1.62–12	9.06–13	4.96–13	2.59–13	1.20–13	4.57–14	1.32–14	2.91–15	4.87–16	5.56–17	3.85–18
$11f_{7/2}$	2.14–11	1.20–11	6.78–12	3.81–12	2.14–12	1.19–12	6.53–13	3.40–13	1.58–13	5.94–14	1.71–14	3.74–15	6.23–16	7.09–17	4.91–18
$11g_{7/2}$	2.10–11	1.18–11	6.66–12	3.74–12	2.10–12	1.16–12	6.26–13	3.12–13	1.32–13	4.32–14	1.07–14	2.11–15	3.30–16	3.66–17	2.47–18
$11g_{9/2}$	2.61–11	1.47–11	8.26–12	4.65–12	2.60–12	1.44–12	7.76–13	3.86–13	1.63–13	5.32–14	1.32–14	2.59–15	4.04–16	4.47–17	3.02–18
$11h_{9/2}$	2.34–11	1.32–11	7.42–12	4.17–12	2.33–12	1.28–12	6.73–13	3.16–13	1.20–13	3.44–14	7.66–15	1.41–15	2.14–16	2.35–17	1.58–18
$11h_{11/2}$	2.80–11	1.57–11	8.85–12	4.97–12	2.78–12	1.53–12	8.02–13	3.77–13	1.43–13	4.09–14	9.09–15	1.67–15	2.54–16	2.78–17	1.87–18
$11i_{11/2}$	2.22–11	1.25–11	7.01–12	3.94–12	2.19–12	1.19–12	6.06–13	2.66–13	9.06–14	2.32–14	4.79–15	8.51–16	1.27–16	1.39–17	9.33–19
$11i_{13/2}$	2.57–11	1.45–11	8.15–12	4.57–12	2.54–12	1.38–12	7.04–13	3.08–13	1.05–13	2.69–14	5.55–15	9.85–16	1.47–16	1.61–17	1.08–18
$12s_{1/2}$	3.11–12	1.75–12	9.85–13	5.55–13	3.12–13	1.75–13	9.73–14	5.34–14	2.85–14	1.46–14	7.08–15	3.04–15	1.02–15	2.28–16	3.25–17
$12p_{1/2}$	3.41–12	1.92–12	1.08–12	6.09–13	3.42–13	1.92–13	1.07–13	5.90–14	3.15–14	1.59–14	7.12–15	2.60–15	6.96–16	1.19–16	1.26–17
$12p_{3/2}$	8.12–12	4.57–12	2.57–12	1.45–12	8.14–13	4.55–13	2.52–13	1.36–13	7.04–14	3.35–14	1.39–14	4.64–15	1.13–15	1.74–16	1.60–17
$12d_{3/2}$	8.59–12	4.84–12	2.72–12	1.53–12	8.60–13	4.81–13	2.66–13	1.42–13	7.09–14	3.08–14	1.08–14	2.87–15	5.55–16	6.93–17	4.96–18
$12d_{5/2}$	1.25–11	7.06–12	3.97–12	2.24–12	1.26–12	7.02–13	3.87–13	2.07–13	1.02–13	4.39–14	1.51–14	3.94–15	7.46–16	9.17–17	6.50–18
$12f_{5/2}$	1.30–11	7.34–12	4.13–12	2.33–12	1.31–12	7.27–13	3.98–13	2.07–13	9.58–14	3.62–14	1.04–14	2.30–15	3.86–16	4.38–17	2.99–18
$12f_{7/2}$	1.72–11	9.68–12	5.45–12	3.07–12	1.72–12	9.59–13	5.24–13	2.72–13	1.25–13	4.71–14	1.35–14	2.96–15	4.93–16	5.58–17	3.81–18
$12g_{7/2}$	1.72–11	9.67–12	5.45–12	3.06–12	1.72–12	9.51–13	5.11–13	2.54–13	1.07–13	3.50–14	8.68–15	1.71–15	2.67–16	2.95–17	2.00–18
$12g_{9/2}$	2.13–11	1.20–11	6.76–12	3.80–12	2.13–12	1.18–12	6.34–13	3.15–13	1.32–13	4.31–14	1.07–14	2.09–15	3.27–16	3.62–17	2.44–18
$12h_{9/2}$	1.99–11	1.12–11	6.29–12	3.54–12	1.97–12	1.09–12	5.70–13	2.68–13	1.01–13	2.90–14	6.45–15	1.19–15	1.80–16	1.97–17	1.33–18
$12h_{11/2}$	2.37–11	1.33–11	7.51–12	4.22–12	2.36–12	1.30–12	6.80–13	3.19–13	1.21–13	3.45–14	7.65–15	1.41–15	2.14–16	2.34–17	1.58–18
$12i_{11/2}$	2.00–11	1.12–11	6.32–12	3.55–12	1.97–12	1.07–12	5.46–13	2.39–13	8.14–14	2.09–14	4.30–15	7.64–16	1.14–16	1.25–17	8.37–19
$12i_{13/2}$	2.32–11	1.30–11	7.34–12	4.12–12	2.29–12	1.25–12	6.34–13	2.78–13	9.44–14	2.42–14	4.98–15	8.84–16	1.32–16	1.44–17	9.69–19
total	8.48–09	4.77–09	2.68–09	1.51–09	8.43–10	4.66–10	2.51–10	1.29–10	6.22–11	2.75–11	1.09–11	3.72–12	9.96–13	1.81–13	2.15–14
$\mathbf{W^{73+}}$															
$1s_{1/2}$	1.34–09	7.53–10	4.23–10	2.38–10	1.34–10	7.52–11	4.23–11	2.37–11	1.33–11	7.31–12	3.87–12	1.84–12	6.90–13	1.72–13	2.75–14
$2s_{1/2}$	4.09–10	2.30–10	1.29–10	7.27–11	4.09–11	2.30–11	1.29–11	7.26–12	4.07–12	2.26–12	1.21–12	5.77–13	2.12–13	5.06–14	7.63–15
$2p_{1/2}$	4.94–10	2.78–10	1.56–10	8.79–11	4.94–11	2.78–11	1.56–11	8.69–12	4.77–12	2.50–12	1.17–12	4.47–13	1.24–13	2.20–14	2.39–15
$2p_{3/2}$	7.85–10	4.41–10	2.48–10	1.40–10	7.85–11	4.41–11	2.47–11	1.37–11	7.49–12	3.86–12	1.74–12	6.28–13	1.62–13	2.61–14	2.50–15
$3s_{1/2}$	1.32–10	7.43–11	4.18–11	2.35–11	1.32–11	7.43–12	4.18–12	2.35–12	1.32–12	7.37–13	3.93–13	1.84–13	6.59–14	1.53–14	2.26–15
$3p_{1/2}$	1.62–10	9.12–11	5.13–11	2.88–11	1.62–11	9.11–12	5.12–12	2.86–12	1.58–12	8.36–13	3.97–13	1.53–13	4.24–14	7.49–15	8.09–16
$3p_{3/2}$	2.98–10	1.68–10	9.42–11	5.30–11	2.98–11	1.67–11	9.39–12	5.23–12	2.85–12	1.47–12	6.63–13	2.37–13	6.04–14	9.64–15	9.14–16
$3d_{3/2}$	2.22–10	1.25–10	7.03–11	3.95–11	2.22–11	1.25–11	6.94–12	3.79–12	1.96–12	8.96–13	3.30–13	9.12–14	1.80–14	2.29–15	1.69–16
$3d_{5/2}$	3.06–10	1.72–10	9.69–11	5.45–11	3.06–11	1.72–11	9.55–12	5.21–12	2.68–12	1.22–12	4.41–13	1.20–13	2.33–14	2.92–15	2.13–16
$4s_{1/2}$	5.97–11	3.36–11	1.89–11	1.06–11	5.97–12	3.36–12	1.89–12	1.06–12	5.98–13	3.32–13	1.75–13	8.04–14	2.83–14	6.48–15	9.42–16
$4p_{1/2}$	7.18–11	4.04–11	2.27–11	1.28–11	7.18–12	4.04–12	2.27–12	1.27–12	7.03–13	3.74–13	1.77–13	6.78–14	1.87–14	3.29–15	3.53–16
$4p_{3/2}$	1.43–10	8.04–11	4.52–11	2.54–11	1.43–11	8.03–12	4.50–12	2.51–12	1.37–12	7.01–13	3.13–13	1.11–13	2.79–14	4.41–15	4.15–16
$4d_{3/2}$	1.35–10	7.56–11	4.25–11	2.39–11	1.34–11	7.54–12	4.20–12	2.30–12	1.19–12	5.44–13	2.00–13	5.52–14	1.09–14	1.38–15	1.02–16
$4d_{5/2}$	1.89–10	1.06–10	5.98–11	3.36–11	1.89–11	1.06–11	5.90–12	3.22–12	1.66–12	7.52–13	2.72–13	7.36–14	1.43–14	1.78–15	1.30–16
$4f_{5/2}$	1.06–10	5.95–11	3.35–11	1.88–11	1.06–11	5.90–12	3.25–12	1.71–12	8.15–13	3.18–13	9.44–14	2.12–14	3.57–15	4.09–16	2.80–17
$4f_{7/2}$	1.36–10	7.64–11	4.30–11	2.42–11	1.36–11	7.57–12	4.16–12	2.20–12	1.04–12	4.05–13	1.20–13	2.67–14	4.48–15	5.12–16	3.51–17

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T\,(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$5s_{1/2}$	3.25–11	1.83–11	1.03–11	5.79–12	3.25–12	1.83–12	1.03–12	5.79–13	3.25–13	1.79–13	9.28–14	4.20–14	1.46–14	3.31–15	4.78–16
$5p_{1/2}$	3.82–11	2.15–11	1.21–11	6.80–12	3.82–12	2.15–12	1.21–12	6.77–13	3.75–13	1.99–13	9.39–14	3.56–14	9.78–15	1.71–15	1.83–16
$5p_{3/2}$	8.02–11	4.51–11	2.54–11	1.43–11	8.01–12	4.50–12	2.52–12	1.40–12	7.62–13	3.88–13	1.71–13	5.98–14	1.49–14	2.35–15	2.20–16
$5d_{3/2}$	8.12–11	4.57–11	2.57–11	1.44–11	8.12–12	4.55–12	2.54–12	1.39–12	7.18–13	3.27–13	1.20–13	3.29–14	6.47–15	8.19–16	6.04–17
$5d_{5/2}$	1.16–10	6.50–11	3.66–11	2.06–11	1.16–11	6.48–12	3.61–12	1.97–12	1.01–12	4.57–13	1.64–13	4.42–14	8.54–15	1.07–15	7.77–17
$5f_{5/2}$	9.09–11	5.12–11	2.88–11	1.62–11	9.07–12	5.07–12	2.79–12	1.47–12	7.01–13	2.73–13	8.11–14	1.82–14	3.06–15	3.50–16	2.40–17
$5f_{7/2}$	1.18–10	6.62–11	3.72–11	2.09–11	1.17–11	6.56–12	3.61–12	1.90–12	9.03–13	3.50–13	1.03–13	2.31–14	3.87–15	4.42–16	3.02–17
$5g_{7/2}$	5.21–11	2.93–11	1.65–11	9.26–12	5.19–12	2.88–12	1.56–12	7.83–13	3.36–13	1.12–13	2.83–14	5.61–15	8.80–16	9.76–17	6.60–18
$5g_{9/2}$	6.38–11	3.59–11	2.02–11	1.13–11	6.35–12	3.52–12	1.90–12	9.57–13	4.10–13	1.36–13	3.43–14	6.80–15	1.07–15	1.18–16	7.99–18
$6s_{1/2}$	1.99–11	1.12–11	6.30–12	3.55–12	1.99–12	1.12–12	6.31–13	3.54–13	1.98–13	1.08–13	5.51–14	2.46–14	8.46–15	1.91–15	2.75–16
$6p_{1/2}$	2.29–11	1.29–11	7.26–12	4.08–12	2.30–12	1.29–12	7.25–13	4.07–13	2.25–13	1.19–13	5.56–14	2.09–14	5.72–15	9.96–16	1.06–16
$6p_{3/2}$	4.99–11	2.81–11	1.58–11	8.87–12	4.99–12	2.80–12	1.57–12	8.71–13	4.71–13	2.37–13	1.04–13	3.58–14	8.88–15	1.39–15	1.30–16
$6d_{3/2}$	5.21–11	2.93–11	1.65–11	9.27–12	5.21–12	2.92–12	1.63–12	8.88–13	4.59–13	2.08–13	7.56–14	2.07–14	4.05–15	5.13–16	3.78–17
$6d_{5/2}$	7.47–11	4.20–11	2.36–11	1.33–11	7.47–12	4.19–12	2.33–12	1.27–12	6.51–13	2.92–13	1.04–13	2.80–14	5.38–15	6.70–16	4.89–17
$6f_{5/2}$	6.72–11	3.78–11	2.13–11	1.19–11	6.70–12	3.74–12	2.06–12	1.09–12	5.17–13	2.01–13	5.95–14	1.33–14	2.24–15	2.56–16	1.76–17
$6f_{7/2}$	8.74–11	4.92–11	2.76–11	1.55–11	8.72–12	4.87–12	2.68–12	1.41–12	6.69–13	2.59–13	7.62–14	1.69–14	2.84–15	3.24–16	2.22–17
$6g_{7/2}$	5.82–11	3.27–11	1.84–11	1.03–11	5.79–12	3.22–12	1.74–12	8.75–13	3.75–13	1.25–13	3.15–14	6.25–15	9.82–16	1.09–16	7.36–18
$6g_{9/2}$	7.15–11	4.02–11	2.26–11	1.27–11	7.12–12	3.95–12	2.14–12	1.07–12	4.60–13	1.53–13	3.84–14	7.61–15	1.19–15	1.32–16	8.94–18
$6h_{9/2}$	2.61–11	1.47–11	8.26–12	4.63–12	2.59–12	1.42–12	7.51–13	3.56–13	1.37–13	3.96–14	8.90–15	1.65–15	2.50–16	2.74–17	1.85–18
$6h_{11/2}$	3.09–11	1.74–11	9.78–12	5.49–12	3.06–12	1.69–12	8.89–13	4.21–13	1.61–13	4.68–14	1.05–14	1.94–15	2.95–16	3.23–17	2.18–18
$7s_{1/2}$	1.32–11	7.45–12	4.19–12	2.35–12	1.32–12	7.45–13	4.18–13	2.34–13	1.30–13	7.00–14	3.53–14	1.56–14	5.33–15	1.20–15	1.72–16
$7p_{1/2}$	1.50–11	8.43–12	4.74–12	2.67–12	1.50–12	8.43–13	4.74–13	2.65–13	1.46–13	7.67–14	3.56–14	1.33–14	3.62–15	6.29–16	6.70–17
$7p_{3/2}$	3.34–11	1.88–11	1.06–11	5.95–12	3.34–12	1.88–12	1.05–12	5.81–13	3.12–13	1.56–13	6.73–14	2.31–14	5.69–15	8.89–16	8.26–17
$7d_{3/2}$	3.54–11	1.99–11	1.12–11	6.29–12	3.53–12	1.98–12	1.10–12	6.01–13	3.09–13	1.39–13	5.04–14	1.37–14	2.68–15	3.39–16	2.49–17
$7d_{5/2}$	5.10–11	2.87–11	1.61–11	9.07–12	5.09–12	2.86–12	1.59–12	8.63–13	4.41–13	1.97–13	6.98–14	1.86–14	3.57–15	4.44–16	3.25–17
$7f_{5/2}$	4.89–11	2.75–11	1.55–11	8.70–12	4.88–12	2.73–12	1.50–12	7.92–13	3.75–13	1.45–13	4.29–14	9.58–15	1.61–15	1.84–16	1.26–17
$7f_{7/2}$	6.39–11	3.60–11	2.02–11	1.14–11	6.38–12	3.56–12	1.96–12	1.03–12	4.87–13	1.88–13	5.51–14	1.22–14	2.05–15	2.33–16	1.60–17
$7g_{7/2}$	5.08–11	2.86–11	1.61–11	9.02–12	5.05–12	2.81–12	1.52–12	7.63–13	3.27–13	1.09–13	2.74–14	5.43–15	8.52–16	9.44–17	6.38–18
$7g_{9/2}$	6.26–11	3.52–11	1.98–11	1.11–11	6.23–12	3.46–12	1.87–12	9.38–13	4.02–13	1.33–13	3.35–14	6.62–15	1.04–15	1.15–16	7.77–18
$7h_{9/2}$	3.59–11	2.02–11	1.14–11	6.38–12	3.56–12	1.96–12	1.03–12	4.90–13	1.88–13	5.46–14	1.22–14	2.27–15	3.45–16	3.78–17	2.54–18
$7h_{11/2}$	4.27–11	2.40–11	1.35–11	7.57–12	4.23–12	2.33–12	1.23–12	5.81–13	2.23–13	6.46–14	1.45–14	2.68–15	4.07–16	4.46–17	3.00–18
$7i_{11/2}$	1.32–11	7.43–12	4.18–12	2.34–12	1.30–12	7.09–13	3.62–13	1.60–13	5.50–14	1.42–14	2.95–15	5.26–16	7.88–17	8.58–18	5.77–19
$7i_{13/2}$	1.53–11	8.59–12	4.83–12	2.71–12	1.51–12	8.20–13	4.19–13	1.85–13	6.35–14	1.64–14	3.41–15	6.06–16	9.08–17	9.89–18	6.65–19
$8s_{1/2}$	9.31–12	5.24–12	2.95–12	1.66–12	9.32–13	5.24–13	2.94–13	1.64–13	9.03–14	4.81–14	2.40–14	1.05–14	3.57–15	8.01–16	1.15–16
$8p_{1/2}$	1.04–11	5.85–12	3.29–12	1.85–12	1.04–12	5.85–13	3.29–13	1.84–13	1.01–13	5.24–14	2.41–14	8.99–15	2.44–15	4.22–16	4.49–17
$8p_{3/2}$	2.37–11	1.33–11	7.49–12	4.21–12	2.37–12	1.33–12	7.42–13	4.09–13	2.18–13	1.08–13	4.61–14	1.57–14	3.86–15	6.01–16	5.58–17
$8d_{3/2}$	2.51–11	1.41–11	7.96–12	4.47–12	2.51–12	1.41–12	7.84–13	4.26–13	2.18–13	9.77–14	3.51–14	9.51–15	1.85–15	2.34–16	1.71–17
$8d_{5/2}$	3.64–11	2.05–11	1.15–11	6.48–12	3.64–12	2.04–12	1.13–12	6.14–13	3.12–13	1.38–13	4.87–14	1.29–14	2.48–15	3.08–16	2.25–17
$8f_{5/2}$	3.62–11	2.04–11	1.15–11	6.45–12	3.62–12	2.02–12	1.11–12	5.85–13	2.76–13	1.07–13	3.14–14	6.99–15	1.17–15	1.34–16	9.19–18
$8f_{7/2}$	4.74–11	2.67–11	1.50–11	8.44–12	4.74–12	2.64–12	1.45–12	7.64–13	3.60–13	1.38–13	4.04–14	8.94–15	1.49–15	1.70–16	1.17–17
$8g_{7/2}$	4.14–11	2.33–11	1.31–11	7.37–12	4.13–12	2.29–12	1.24–12	6.22–13	2.66–13	8.84–14	2.22–14	4.40–15	6.90–16	7.64–17	5.17–18
$8g_{9/2}$	5.12–11	2.88–11	1.62–11	9.09–12	5.09–12	2.83–12	1.53–12	7.67–13	3.27–13	1.08–13	2.72–14	5.37–15	8.42–16	9.32–17	6.30–18
$8h_{9/2}$	3.62–11	2.03–11	1.14–11	6.42–12	3.59–12	1.97–12	1.04–12	4.93–13	1.89–13	5.48–14	1.23–14	2.27–15	3.46–16	3.79–17	2.55–18
$8h_{11/2}$	4.30–11	2.42–11	1.36–11	7.63–12	4.26–12	2.35–12	1.24–12	5.85–13	2.24–13	6.49–14	1.45–14	2.69–15	4.09–16	4.47–17	3.01–18
$8i_{11/2}$	2.17–11	1.22–11	6.85–12	3.84–12	2.14–12	1.16–12	5.94–13	2.62–13	9.03–14	2.34–14	4.84–15	8.62–16	1.29–16	1.41–17	9.45–19
$8i_{13/2}$	2.51–11	1.41–11	7.93–12	4.45–12	2.48–12	1.35–12	6.88–13	3.04–13	1.04–13	2.70–14	5.59–15	9.95–16	1.49–16	1.62–17	1.09–18
$9s_{1/2}$	6.84–12	3.85–12	2.17–12	1.22–12	6.85–13	3.85–13	2.16–13	1.20–13	6.55–14	3.45–14	1.71–14	7.41–15	2.51–15	5.61–16	8.02–17
$9p_{1/2}$	7.56–12	4.25–12	2.39–12	1.35–12	7.57–13	4.25–13	2.39–13	1.33–13	7.25–14	3.74–14	1.71–14	6.34–15	1.71–15	2.97–16	3.15–17
$9p_{3/2}$	1.75–11	9.82–12	5.53–12	3.11–12	1.75–12	9.80–13	5.47–13	3.00–13	1.59–13	7.78–14	3.30–14	1.12–14	2.74–15	4.25–16	3.94–17
$9d_{3/2}$	1.86–11	1.04–11	5.88–12	3.31–12	1.86–12	1.04–12	5.78–13	3.13–13	1.60–13	7.10–14	2.54–14	6.85–15	1.33–15	1.68–16	1.22–17
$9d_{5/2}$	2.70–11	1.52–11	8.53–12	4.80–12	2.70–12	1.51–12	8.38–13	4.53–13	2.29–13	1.01–13	3.53–14	9.34–15	1.78–15	2.22–16	1.64–17
$9f_{5/2}$	2.74–11	1.54–11	8.68–12	4.88–12	2.74–12	1.53–12	8.40–13	4.41–13	2.08–13	7.99–14	2.34–14	5.21–15	8.73–16	9.98–17	6.83–18
$9f_{7/2}$	3.60–11	2.02–11	1.14–11	6.40–12	3.59–12	2.00–12	1.10–12	5.78–13	2.71–13	1.04–13	3.02–14	6.67–15	1.11–15	1.27–16	8.68–18
$9g_{7/2}$	3.33–11	1.87–11	1.05–11	5.92–12	3.31–12	1.84–12	9.93–13	4.98–13	2.13–13	7.05–14	1.77–14	3.50–15	5.49–16	6.08–17	4.11–18
$9g_{9/2}$	4.11–11	2.31–11	1.30–11	7.32–12	4.10–12	2.27–12	1.23–12	6.15–13	2.62–13	8.66–14	2.17–14	4.28–15	6.70–16	7.42–17	5.01–18
$9h_{9/2}$	3.27–11	1.84–11	1.03–11	5.81–12	3.24–12	1.79–12	9.41–13	4.45–13	1.71–13	4.94–14	1.11–14	2.04–15	3.11–16	3.41–17	2.29–18
$9h_{11/2}$	3.89–11	2.19–11	1.23–11	6.91–12	3.86–12	2.12–12	1.12–12	5.29–13	2.03–13	5.85–14	1.31–14	2.42–15	3.68–16	4.03–17	2.71–18
$9i_{11/2}$	2.47–11	1.39–11	7.81–12	4.38–12	2.44–12	1.33–12	6.78–13	2.99–13	1.03–13	2.66–14	5.51–15	9.80–16	1.47–16	1.60–17	1.08–18
$9i_{13/2}$	2.86–11	1.61–11	9.05–12	5.08–12	2.82–12	1.54–12	7.85–13	3.46–13	1.19–13	3.07–14	6.37–15	1.13–15	1.70–16	1.85–17	1.24–18
$10s_{1/2}$	5.20–12	2.92–12	1.65–12	9.27–13	5.21–13	2.92–13	1.64–13	9.06–14	4.91–14	2.56–14	1.25–14	5.42–15	1.83–15	4.08–16	5.82–17
$10p_{1/2}$	5.69–12	3.20–12	1.80–12	1.01–12	5.70–13	3.20–13	1.79–13	9.96–14	5.40–14	2.77–14	1.26–14	4.64–15	1.25–15	2.16–16	2.31–17
$10p_{3/2}$	1.33–11	7.50–12	4.22–12	2.37–12	1.33–12	7.48–13	4.16–13	2.28–13	1.19–13	5.79–14	2.44–14	8.21–15	2.01–15	3.11–16	2.88–17
$10d_{3/2}$	1.41–11	7.96–12	4.48–12	2.52–12	1.42–12	7.93–13	4.40–13	2.38–13	1.20–13	5.32–14	1.89–14	5.09–15	9.88–16	1.25–16	9.13–18
$10d_{5/2}$	2.06–11	1.16–11	6.52–12	3.67–12	2.06–12	1.15–12	6.39–13	3.44–13	1.73–13	7.54–14	2.63–14	6.95–15	1.33–15	1.65–16	1.16–17
$10f_{5/2}$	2.12–11	1.19–11	6.71–12	3.77–12	2.12–12	1.18–12	6.49–13	3.40–13	1.60–13	6.11–14	1.79–14	3.96–15	6.64–16	7.58–17	5.19–18

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$10f_{7/2}$	2.79–11	1.57–11	8.83–12	4.96–12	2.78–12	1.55–12	8.52–13	4.46–13	2.08–13	7.93–14	2.30–14	5.08–15	8.47–16	9.65–17	6.60–18
$10g_{7/2}$	2.67–11	1.50–11	8.46–12	4.76–12	2.66–12	1.48–12	7.98–13	4.00–13	1.70–13	5.63–14	1.41–14	2.78–15	4.36–16	4.83–17	3.27–18
$10g_{9/2}$	3.31–11	1.86–11	1.05–11	5.89–12	3.30–12	1.83–12	9.87–13	4.94–13	2.10–13	6.92–14	1.73–14	3.41–15	5.34–16	5.91–17	3.99–18
$10h_{9/2}$	2.83–11	1.59–11	8.96–12	5.03–12	2.81–12	1.55–12	8.15–13	3.85–13	1.47–13	4.26–14	9.53–15	1.76–15	2.68–16	2.93–17	1.97–18
$10h_{11/2}$	3.37–11	1.90–11	1.07–11	6.00–12	3.35–12	1.84–12	9.71–13	4.58–13	1.75–13	5.05–14	1.13–14	2.09–15	3.17–16	3.47–17	2.34–18
$10i_{11/2}$	2.45–11	1.38–11	7.75–12	4.35–12	2.42–12	1.32–12	6.73–13	2.97–13	1.02–13	2.63–14	5.45–15	9.70–16	1.45–16	1.58–17	1.06–18
$10i_{13/2}$	2.84–11	1.60–11	8.99–12	5.04–12	2.81–12	1.53–12	7.80–13	3.44–13	1.18–13	3.05–14	6.31–15	1.12–15	1.68–16	1.83–17	1.23–18
$11s_{1/2}$	4.06–12	2.29–12	1.29–12	7.24–13	4.07–13	2.28–13	1.27–13	7.02–14	3.78–14	1.95–14	9.48–15	4.08–15	1.37–15	3.06–16	4.36–17
$11p_{1/2}$	4.41–12	2.48–12	1.40–12	7.86–13	4.42–13	2.48–13	1.39–13	7.68–14	4.14–14	2.10–14	9.50–15	3.49–15	9.41–16	1.62–16	1.72–17
$11p_{3/2}$	1.04–11	5.87–12	3.31–12	1.86–12	1.05–12	5.85–13	3.25–13	1.77–13	9.21–14	4.43–14	1.85–14	6.21–15	1.51–15	2.35–16	2.17–17
$11d_{3/2}$	1.11–11	6.23–12	3.51–12	1.97–12	1.11–12	6.20–13	3.43–13	1.85–13	9.29–14	4.08–14	1.44–14	3.88–15	7.51–16	9.39–17	6.72–18
$11d_{5/2}$	1.61–11	9.07–12	5.11–12	2.87–12	1.61–12	9.02–13	4.99–13	2.68–13	1.34–13	5.80–14	2.01–14	5.30–15	1.01–15	1.33–16	8.95–18
$11f_{5/2}$	1.67–11	9.41–12	5.30–12	2.98–12	1.67–12	9.32–13	5.11–13	2.67–13	1.25–13	4.76–14	1.39–14	3.07–15	5.14–16	5.87–17	4.02–18
$11f_{7/2}$	2.20–11	1.24–11	6.98–12	3.92–12	2.20–12	1.23–12	6.72–13	3.51–13	1.63–13	6.18–14	1.79–14	3.94–15	6.58–16	7.49–17	5.12–18
$11g_{7/2}$	2.16–11	1.22–11	6.86–12	3.85–12	2.16–12	1.20–12	6.45–13	3.23–13	1.37–13	4.52–14	1.13–14	2.23–15	3.49–16	3.87–17	2.61–18
$11g_{9/2}$	2.68–11	1.51–11	8.50–12	4.78–12	2.67–12	1.48–12	7.99–13	3.99–13	1.69–13	5.56–14	1.39–14	2.73–15	4.28–16	4.73–17	3.20–18
$11h_{9/2}$	2.41–11	1.36–11	7.64–12	4.29–12	2.40–12	1.32–12	6.94–13	3.27–13	1.25–13	3.61–14	8.07–15	1.49–15	2.27–16	2.48–17	1.67–18
$11h_{11/2}$	2.88–11	1.62–11	9.11–12	5.11–12	2.86–12	1.57–12	8.27–13	3.90–13	1.49–13	4.29–14	9.57–15	1.77–15	2.69–16	2.94–17	1.98–18
$11i_{11/2}$	2.28–11	1.28–11	7.21–12	4.05–12	2.25–12	1.23–12	6.26–13	2.76–13	9.46–14	2.44–14	5.06–15	9.00–16	1.35–16	1.47–17	9.87–19
$11i_{13/2}$	2.65–11	1.49–11	8.38–12	4.70–12	2.62–12	1.42–12	7.26–13	3.20–13	1.10–13	2.83–14	5.85–15	1.04–15	1.56–16	1.70–17	1.14–18
$12s_{1/2}$	3.24–12	1.82–12	1.03–12	5.78–13	3.25–13	1.82–13	1.01–13	5.56–14	2.97–14	1.52–14	7.34–15	3.14–15	1.05–15	2.35–16	3.35–17
$12p_{1/2}$	3.50–12	1.97–12	1.11–12	6.24–13	3.51–13	1.97–13	1.10–13	6.05–14	3.24–14	1.63–14	7.35–15	2.69–15	7.24–16	1.25–16	1.32–17
$12p_{3/2}$	8.35–12	4.70–12	2.65–12	1.49–12	8.36–13	4.68–13	2.59–13	1.40–13	7.25–14	3.46–14	1.44–14	4.81–15	1.17–15	1.81–16	1.67–17
$12d_{3/2}$	8.83–12	4.97–12	2.80–12	1.58–12	8.85–13	4.94–13	2.73–13	1.46–13	7.32–14	3.20–14	1.13–14	3.02–15	5.82–16	7.18–17	5.07–18
$12d_{5/2}$	1.29–11	7.25–12	4.08–12	2.30–12	1.29–12	7.21–13	3.98–13	2.13–13	1.05–13	4.55–14	1.57–14	4.13–15	7.84–16	9.57–17	6.73–18
$12f_{5/2}$	1.34–11	7.56–12	4.25–12	2.39–12	1.34–12	7.48–13	4.10–13	2.13–13	9.92–14	3.77–14	1.10–14	2.42–15	4.05–16	4.62–17	3.16–18
$12f_{7/2}$	1.77–11	9.96–12	5.61–12	3.16–12	1.77–12	9.86–13	5.39–13	2.80–13	1.30–13	4.90–14	1.42–14	3.11–15	5.19–16	5.90–17	4.03–18
$12g_{7/2}$	1.77–11	9.95–12	5.60–12	3.15–12	1.76–12	9.78–13	5.27–13	2.63–13	1.11–13	3.66–14	9.13–15	1.80–15	2.82–16	3.13–17	2.11–18
$12g_{9/2}$	2.20–11	1.24–11	6.95–12	3.91–12	2.19–12	1.21–12	6.53–13	3.26–13	1.38–13	4.51–14	1.12–14	2.21–15	3.46–16	3.83–17	2.58–18
$12h_{9/2}$	2.04–11	1.15–11	6.47–12	3.64–12	2.03–12	1.12–12	5.88–13	2.77–13	1.06–13	3.04–14	6.80–15	1.25–15	1.91–16	2.09–17	1.41–18
$12h_{11/2}$	2.44–11	1.37–11	7.73–12	4.34–12	2.42–12	1.33–12	7.01–13	3.30–13	1.26–13	3.62–14	8.06–15	1.49–15	2.26–16	2.48–17	1.67–18
$12i_{11/2}$	2.05–11	1.16–11	6.50–12	3.65–12	2.03–12	1.10–12	5.64–13	2.48–13	8.50–14	2.19–14	4.54–15	8.07–16	1.21–16	1.32–17	8.85–19
$12i_{13/2}$	2.39–11	1.34–11	7.55–12	4.24–12	2.36–12	1.28–12	6.55–13	2.88–13	9.86–14	2.54–14	5.26–15	9.34–16	1.40–16	1.52–17	1.02–18
total	1.01–08	5.66–09	3.18–09	1.79–09	1.00–09	5.55–10	3.01–10	1.57–10	7.75–11	3.58–11	1.52–11	5.70–12	1.72–12	3.59–13	4.97–14
W^{74+}															
$1s_{1/2}$	2.70–09	1.52–09	8.53–10	4.80–10	2.70–10	1.52–10	8.53–11	4.78–11	2.67–11	1.47–11	7.81–12	3.72–12	1.39–12	3.47–13	5.56–14
$2s_{1/2}$	4.20–10	2.36–10	1.33–10	7.47–11	4.20–11	2.36–11	1.33–11	7.46–12	4.18–12	2.32–12	1.24–12	5.91–13	2.17–13	5.17–14	7.80–15
$2p_{1/2}$	5.07–10	2.85–10	1.60–10	9.01–11	5.07–11	2.85–11	1.60–11	8.91–12	4.89–12	2.56–12	1.21–12	4.63–13	1.29–13	2.30–14	2.50–15
$2p_{3/2}$	8.02–10	4.51–10	2.54–10	1.43–10	8.01–11	4.50–11	2.52–11	1.40–11	7.66–12	3.95–12	1.79–12	6.47–13	1.67–13	2.70–14	2.60–15
$3s_{1/2}$	1.36–10	7.67–11	4.31–11	2.43–11	1.36–11	7.67–12	4.32–12	2.43–12	1.36–12	7.59–13	4.04–13	1.89–13	6.77–14	1.57–14	2.32–15
$3p_{1/2}$	1.66–10	9.35–11	5.26–11	2.96–11	1.66–11	9.35–12	5.25–12	2.93–12	1.62–12	8.59–13	4.09–13	1.58–13	4.41–14	7.81–15	8.47–16
$3p_{3/2}$	3.05–10	1.72–10	9.65–11	5.43–11	3.05–11	1.71–11	9.61–12	5.35–12	2.92–12	1.51–12	6.83–13	2.45–13	6.26–14	1.00–14	9.53–16
$3d_{3/2}$	2.29–10	1.29–10	7.25–11	4.07–11	2.29–11	1.28–11	7.15–12	3.91–12	2.03–12	9.30–13	3.44–13	9.59–14	1.90–14	2.43–15	1.80–16
$3d_{5/2}$	3.15–10	1.77–10	9.96–11	5.60–11	3.15–11	1.76–11	9.82–12	5.36–12	2.77–12	1.26–12	4.59–13	1.26–13	2.45–14	3.08–15	2.26–16
$4s_{1/2}$	6.18–11	3.48–11	1.96–11	1.10–11	6.19–12	3.48–12	1.96–12	1.10–12	6.18–13	3.43–13	1.80–13	8.27–14	2.91–14	6.66–15	9.69–16
$4p_{1/2}$	7.36–11	4.14–11	2.33–11	1.31–11	7.37–12	4.14–12	2.33–12	1.30–12	7.22–13	3.84–13	1.83–13	7.02–14	1.95–14	3.43–15	3.70–16
$4p_{3/2}$	1.47–10	8.25–11	4.64–11	2.61–11	1.47–11	8.24–12	4.62–12	2.57–12	1.40–12	7.20–13	3.23–13	1.14–13	2.89–14	4.59–15	4.33–16
$4d_{3/2}$	1.38–10	7.78–11	4.38–11	2.46–11	1.38–11	7.75–12	4.32–12	2.36–12	1.23–12	5.64–13	2.09–13	5.79–14	1.15–14	1.46–15	1.08–16
$4d_{5/2}$	1.94–10	1.09–10	6.15–11	3.46–11	1.94–11	1.09–11	6.06–12	3.31–12	1.71–12	7.78–13	2.83–13	7.71–14	1.50–14	1.88–15	1.38–16
$4f_{5/2}$	1.09–10	6.13–11	3.45–11	1.94–11	1.09–11	6.07–12	3.34–12	1.77–12	8.44–13	3.31–13	9.91–14	2.24–14	3.78–15	4.33–16	2.97–17
$4f_{7/2}$	1.40–10	7.86–11	4.42–11	2.49–11	1.39–11	7.79–12	4.29–12	2.26–12	1.08–12	4.21–13	1.25–13	2.81–14	4.73–15	5.42–16	3.71–17
$5s_{1/2}$	3.37–11	1.90–11	1.07–11	6.00–12	3.38–12	1.90–12	1.07–12	6.00–13	3.36–13	1.85–13	9.58–14	4.32–14	1.50–14	3.41–15	4.92–16
$5p_{1/2}$	3.92–11	2.20–11	1.24–11	6.97–12	3.92–12	2.20–12	1.24–12	6.94–13	3.85–13	2.05–13	9.68–14	3.69–14	1.02–14	1.78–15	1.91–16
$5p_{3/2}$	8.22–11	4.62–11	2.60–11	1.46–11	8.22–12	4.62–12	2.59–12	1.44–12	7.83–13	3.99–13	1.77–13	6.19–14	1.55–14	2.45–15	2.29–16
$5d_{3/2}$	8.36–11	4.70–11	2.64–11	1.49–11	8.35–12	4.68–12	2.61–12	1.43–12	7.41–13	3.39–13	1.25–13	3.45–14	6.82–15	8.67–16	6.41–17
$5d_{5/2}$	1.19–10	6.68–11	3.76–11	2.11–11	1.19–11	6.66–12	3.71–12	2.02–12	1.04–12	4.73–13	1.71–13	4.63–14	8.98–15	1.12–15	8.24–17
$5f_{5/2}$	9.36–11	5.26–11	2.96–11	1.66–11	9.34–12	5.22–12	2.87–12	1.52–12	7.25–13	2.84–13	8.50–14	1.92–14	3.24–15	3.71–16	2.55–17
$5f_{7/2}$	1.21–10	6.81–11	3.83–11	2.15–11	1.21–11	6.74–12	3.71–12	1.96–12	9.34–13	3.64–13	1.08–13	2.43–14	4.08–15	4.67–16	3.20–17
$5g_{7/2}$	5.36–11	3.02–11	1.70–11	9.53–12	5.34–12	2.96–12	1.60–12	8.09–13	3.49–13	1.17–13	2.97–14	5.92–15	9.32–16	1.03–16	6.99–18
$5g_{9/2}$	6.56–11	3.69–11	2.07–11	1.17–11	6.53–12	3.63–12	1.96–12	9.88–13	4.26–13	1.43–13	3.61–14	7.18–15	1.13–15	1.25–16	8.46–18
$6s_{1/2}$	2.07–11	1.16–11	6.55–12	3.68–12	2.07–12	1.16–12	6.55–13	3.68–13	2.05–13	1.11–13	5.69–14	2.54–14	8.71–15	1.97–15	2.83–16
$6p_{1/2}$	2.35–11	1.32–11	7.44–12	4.19–12	2.35–12	1.32–12	7.44–13	4.17–13	2.31–13	1.22–13	5.73–14	2.17–14	5.95–15	1.04–15	1.11–16
$6p_{3/2}$	5.12–11	2.88–11	1.62–11	9.10–12	5.12–12	2.87–12	1.61–12	8.94–13	4.84–13	2.44–13	1.07–13	3.70–14	9.22–15	1.45–15	1.35–16
$6d_{3/2}$	5.36–11	3.01–11	1.69–11	9.53–12	5.35–12	3.00–12	1.67–12	9.14–13	4.73–13	2.16–13	7.89–14	2.17–14	4.27–15	5.42–16	4.01–17
$6d_{5/2}$	7.68–11	4.32–11	2.43–11	1.37–11	7.67–12	4.30–12	2.39–12	1.31–12	6.71–13	3.02–13	1.09–13	2.93–14	5.66–15	7.07–16	5.20–17

(*continued on next page*)

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$6f_{5/2}$	6.91–11	3.89–11	2.19–11	1.23–11	6.89–12	3.85–12	2.12–12	1.12–12	5.35–13	2.09–13	6.24–14	1.40–14	2.37–15	2.71–16	1.86–17
$6f_{7/2}$	8.98–11	5.05–11	2.84–11	1.60–11	8.97–12	5.01–12	2.76–12	1.46–12	6.92–13	2.69–13	7.98–14	1.78–14	3.00–15	3.43–16	2.35–17
$6g_{7/2}$	5.99–11	3.37–11	1.89–11	1.06–11	5.96–12	3.31–12	1.79–12	9.03–13	3.90–13	1.31–13	3.32–14	6.60–15	1.04–15	1.15–16	7.79–18
$6g_{9/2}$	7.35–11	4.14–11	2.33–11	1.31–11	7.32–12	4.07–12	2.20–12	1.11–12	4.77–13	1.60–13	4.04–14	8.03–15	1.26–15	1.40–16	9.46–18
$6h_{9/2}$	2.68–11	1.51–11	8.49–12	4.77–12	2.66–12	1.47–12	7.74–13	3.68–13	1.42–13	4.16–14	9.38–15	1.74–15	2.65–16	2.90–17	1.95–18
$6h_{11/2}$	3.18–11	1.79–11	1.01–11	5.64–12	3.15–12	1.74–12	9.17–13	4.35–13	1.68–13	4.91–14	1.11–14	2.05–15	3.12–16	3.42–17	2.30–18
$7s_{1/2}$	1.38–11	7.74–12	4.35–12	2.45–12	1.38–12	7.74–13	4.35–13	2.43–13	1.35–13	7.25–14	3.65–14	1.61–14	5.50–15	1.24–15	1.77–16
$7p_{1/2}$	1.54–11	8.64–12	4.86–12	2.73–12	1.54–12	8.64–13	4.85–13	2.72–13	1.50–13	7.88–14	3.67–14	1.38–14	3.77–15	6.56–16	7.02–17
$7p_{3/2}$	3.43–11	1.93–11	1.09–11	6.11–12	3.43–12	1.93–12	1.08–12	5.97–13	3.21–13	1.60–13	6.95–14	2.39–14	5.91–15	9.26–16	8.63–17
$7d_{3/2}$	3.63–11	2.04–11	1.15–11	6.47–12	3.63–12	2.04–12	1.13–12	6.19–13	3.19–13	1.45–13	5.25–14	1.44–14	2.83–15	3.58–16	2.65–17
$7d_{5/2}$	5.24–11	2.94–11	1.66–11	9.32–12	5.24–12	2.93–12	1.63–12	8.88–13	4.55–13	2.03–13	7.27–14	1.95–14	3.75–15	4.69–16	3.44–17
$7f_{5/2}$	5.03–11	2.83–11	1.59–11	8.95–12	5.03–12	2.81–12	1.55–12	8.16–13	3.88–13	1.51–13	4.50–14	1.01–14	1.70–15	1.95–16	1.34–17
$7f_{7/2}$	6.57–11	3.70–11	2.08–11	1.17–11	6.56–12	3.66–12	2.02–12	1.06–12	5.04–13	1.95–13	5.77–14	1.29–14	2.16–15	2.47–16	1.69–17
$7g_{7/2}$	5.22–11	2.94–11	1.65–11	9.28–12	5.20–12	2.89–12	1.56–12	7.88–13	3.39–13	1.14–13	2.88–14	5.73–15	9.01–16	9.99–17	6.75–18
$7g_{9/2}$	6.43–11	3.62–11	2.03–11	1.14–11	6.40–12	3.56–12	1.92–12	9.69–13	4.17–13	1.39–13	3.52–14	6.98–15	1.10–15	1.22–16	8.21–18
$7h_{9/2}$	3.70–11	2.08–11	1.17–11	6.57–12	3.67–12	2.02–12	1.07–12	5.07–13	1.96–13	5.73–14	1.29–14	2.39–15	3.65–16	3.99–17	2.69–18
$7h_{11/2}$	4.39–11	2.47–11	1.39–11	7.79–12	4.35–12	2.40–12	1.27–12	6.01–13	2.32–13	6.77–14	1.52–14	2.82–15	4.30–16	4.71–17	3.17–18
$7i_{11/2}$	1.36–11	7.64–12	4.30–12	2.41–12	1.34–12	7.30–13	3.74–13	1.66–13	5.75–14	1.50–14	3.12–15	5.56–16	8.33–17	9.07–18	6.10–19
$7i_{13/2}$	1.57–11	8.83–12	4.96–12	2.79–12	1.55–12	8.44–13	4.32–13	1.92–13	6.64–14	1.73–14	3.59–15	6.40–16	9.60–17	1.05–17	7.03–19
$8s_{1/2}$	9.68–12	5.44–12	3.06–12	1.72–12	9.69–13	5.45–13	3.06–13	1.71–13	9.38–14	4.99–14	2.48–14	1.09–14	3.69–15	8.25–16	1.18–16
$8p_{1/2}$	1.07–11	5.99–12	3.37–12	1.90–12	1.07–12	6.00–13	3.37–13	1.88–13	1.03–13	5.39–14	2.49–14	9.30–15	2.53–15	4.40–16	4.70–17
$8p_{3/2}$	2.43–11	1.37–11	7.69–12	4.32–12	2.43–12	1.36–12	7.62–13	4.21–13	2.24–13	1.11–13	4.76–14	1.63–14	4.01–15	6.26–16	5.82–17
$8d_{3/2}$	2.58–11	1.45–11	8.17–12	4.60–12	2.58–12	1.45–12	8.06–13	4.39–13	2.25–13	1.01–13	3.66–14	9.98–15	1.96–15	2.48–16	1.86–17
$8d_{5/2}$	3.74–11	2.10–11	1.18–11	6.65–12	3.74–12	2.09–12	1.16–12	6.32–13	3.22–13	1.43–13	5.08–14	1.36–14	2.61–15	3.25–16	2.37–17
$8f_{5/2}$	3.73–11	2.10–11	1.18–11	6.63–12	3.72–12	2.08–12	1.14–12	6.03–13	2.86–13	1.11–13	3.29–14	7.37–15	1.24–15	1.42–16	9.73–18
$8f_{7/2}$	4.88–11	2.74–11	1.54–11	8.68–12	4.87–12	2.72–12	1.50–12	7.87–13	3.72–13	1.44–13	4.23–14	9.41–15	1.58–15	1.80–16	1.23–17
$8g_{7/2}$	4.26–11	2.40–11	1.35–11	7.58–12	4.24–12	2.36–12	1.27–12	6.42–13	2.76–13	9.24–14	2.33–14	4.64–15	7.29–16	8.08–17	5.47–18
$8g_{9/2}$	5.26–11	2.96–11	1.66–11	9.35–12	5.24–12	2.91–12	1.57–12	7.91–13	3.40–13	1.13–13	2.86–14	5.66–15	8.89–16	9.85–17	6.66–18
$8h_{9/2}$	3.72–11	2.09–11	1.18–11	6.60–12	3.69–12	2.03–12	1.07–12	5.10–13	1.97–13	5.74–14	1.29–14	2.40–15	3.65–16	4.00–17	2.69–18
$8h_{11/2}$	4.42–11	2.49–11	1.40–11	7.85–12	4.38–12	2.41–12	1.27–12	6.05–13	2.33–13	6.80–14	1.53–14	2.84–15	4.32–16	4.73–17	3.18–18
$8i_{11/2}$	2.23–11	1.25–11	7.04–12	3.95–12	2.20–12	1.20–12	6.14–13	2.72–13	9.43–14	2.46–14	5.11–15	9.11–16	1.37–16	1.49–17	1.00–18
$8i_{13/2}$	2.58–11	1.45–11	8.15–12	4.58–12	2.55–12	1.39–12	7.10–13	3.15–13	1.09–13	2.84–14	5.90–15	1.05–15	1.58–16	1.72–17	1.15–18
$9s_{1/2}$	7.12–12	4.00–12	2.25–12	1.27–12	7.13–13	4.00–13	2.24–13	1.25–13	6.80–14	3.58–14	1.77–14	7.66–15	2.59–15	5.78–16	8.26–17
$9p_{1/2}$	7.74–12	4.35–12	2.45–12	1.38–12	7.75–13	4.36–13	2.44–13	1.36–13	7.44–14	3.85–14	1.77–14	6.57–15	1.78–15	3.09–16	3.29–17
$9p_{3/2}$	1.79–11	1.01–11	5.68–12	3.19–12	1.80–12	1.01–12	5.62–13	3.09–13	1.63–13	8.01–14	3.41–14	1.16–14	2.84–15	4.43–16	4.12–17
$9d_{3/2}$	1.91–11	1.07–11	6.04–12	3.40–12	1.91–12	1.07–12	5.94–13	3.23–13	1.65–13	7.36–14	2.64–14	7.19–15	1.41–15	1.78–16	1.30–17
$9d_{5/2}$	2.77–11	1.56–11	8.76–12	4.93–12	2.77–12	1.55–12	8.61–13	4.66–13	2.36–13	1.04–13	3.68–14	9.78–15	1.88–15	2.33–16	1.69–17
$9f_{5/2}$	2.82–11	1.59–11	8.92–12	5.02–12	2.81–12	1.57–12	8.64–13	4.55–13	2.15–13	8.32–14	2.46–14	5.49–15	9.23–16	1.06–16	7.24–18
$9f_{7/2}$	3.70–11	2.08–11	1.17–11	6.58–12	3.69–12	2.06–12	1.13–12	5.95–13	2.80–13	1.08–13	3.16–14	7.02–15	1.18–15	1.34–16	9.18–18
$9g_{7/2}$	3.42–11	1.92–11	1.08–11	6.08–12	3.41–12	1.89–12	1.02–12	5.15–13	2.21–13	7.37–14	1.86–14	3.69–15	5.80–16	6.43–17	4.35–18
$9g_{9/2}$	4.23–11	2.38–11	1.34–11	7.52–12	4.21–12	2.34–12	1.26–12	6.35–13	2.72–13	9.05–14	2.28–14	4.51–15	7.08–16	7.84–17	5.30–18
$9h_{9/2}$	3.36–11	1.89–11	1.06–11	5.97–12	3.34–12	1.84–12	9.70–13	4.60–13	1.78–13	5.18–14	1.17–14	2.16–15	3.29–16	3.60–17	2.42–18
$9h_{11/2}$	4.00–11	2.25–11	1.26–11	7.11–12	3.97–12	2.19–12	1.15–12	5.47–13	2.11–13	6.13–14	1.38–14	2.55–15	3.89–16	4.26–17	2.87–18
$9i_{11/2}$	2.54–11	1.43–11	8.02–12	4.51–12	2.51–12	1.37–12	6.99–13	3.10–13	1.07–13	2.79–14	5.81–15	1.04–15	1.55–16	1.69–17	1.14–18
$9i_{13/2}$	2.94–11	1.65–11	9.30–12	5.22–12	2.91–12	1.58–12	8.10–13	3.59–13	1.24–13	3.23–14	6.71–15	1.20–15	1.79–16	1.95–17	1.31–18
$10s_{1/2}$	5.41–12	3.05–12	1.71–12	9.64–13	5.42–13	3.04–13	1.70–13	9.42–14	5.10–14	2.66–14	1.30–14	5.60–15	1.89–15	4.21–16	6.00–17
$10p_{1/2}$	5.83–12	3.28–12	1.85–12	1.04–12	5.84–13	3.28–13	1.84–13	1.02–13	5.54–14	2.84–14	1.30–14	4.80–15	1.30–15	2.26–16	2.41–17
$10p_{3/2}$	1.37–11	7.70–12	4.34–12	2.44–12	1.37–12	7.68–13	4.28–13	2.34–13	1.23–13	5.97–14	2.52–14	8.51–15	2.09–15	3.24–16	3.01–17
$10d_{3/2}$	1.45–11	8.18–12	4.61–12	2.59–12	1.45–12	8.15–13	4.52–13	2.45–13	1.24–13	5.51–14	1.97–14	5.34–15	1.04–15	1.32–16	9.67–18
$10d_{5/2}$	2.12–11	1.19–11	6.70–12	3.77–12	2.12–12	1.18–12	6.56–13	3.54–13	1.78–13	7.81–14	2.74–14	7.28–15	1.39–15	1.73–16	1.23–17
$10f_{5/2}$	2.18–11	1.23–11	6.90–12	3.88–12	2.18–12	1.22–12	6.68–13	3.51–13	1.65–13	6.36–14	1.87–14	4.17–15	7.02–16	8.02–17	5.49–18
$10f_{7/2}$	2.87–11	1.61–11	9.07–12	5.10–12	2.86–12	1.60–12	8.77–13	4.59–13	2.16–13	8.25–14	2.41–14	5.35–15	8.95–16	1.02–16	6.98–18
$10g_{7/2}$	2.75–11	1.55–11	8.70–12	4.89–12	2.74–12	1.52–12	8.21–13	4.13–13	1.77–13	5.88–14	1.48–14	2.94–15	4.61–16	5.11–17	3.45–18
$10g_{9/2}$	3.40–11	1.91–11	1.08–11	6.05–12	3.39–12	1.88–12	1.02–12	5.10–13	2.18–13	7.23–14	1.81–14	3.59–15	5.64–16	6.24–17	4.22–18
$10h_{9/2}$	2.91–11	1.64–11	9.21–12	5.17–12	2.89–12	1.59–12	8.40–13	3.98–13	1.53–13	4.46–14	1.00–14	1.86–15	2.83–16	3.10–17	2.09–18
$10h_{11/2}$	3.47–11	1.95–11	1.10–11	6.17–12	3.44–12	1.90–12	1.00–12	4.74–13	1.82–13	5.30–14	1.19–14	2.20–15	3.35–16	3.67–17	2.47–18
$10i_{11/2}$	2.52–11	1.42–11	7.97–12	4.47–12	2.49–12	1.35–12	6.94–13	3.07–13	1.06–13	2.77–14	5.75–15	1.02–15	1.54–16	1.67–17	1.12–18
$10i_{13/2}$	2.92–11	1.64–11	9.24–12	5.18–12	2.89–12	1.57–12	8.05–13	3.56–13	1.23–13	3.20–14	6.65–15	1.18–15	1.78–16	1.93–17	1.30–18
$11s_{1/2}$	4.23–12	2.38–12	1.34–12	7.54–13	4.24–13	2.38–13	1.33–13	7.31–14	3.93–14	2.03–14	9.82–15	4.21–15	1.42–15	3.15–16	4.49–17
$11p_{1/2}$	4.52–12	2.54–12	1.43–12	8.05–13	4.53–13	2.54–13	1.42–13	7.87–14	4.24–14	2.16–14	9.80–15	3.62–15	9.78–16	1.69–16	1.80–17
$11p_{3/2}$	1.07–11	6.03–12	3.39–12	1.91–12	1.07–12	6.01–13	3.34–13	1.82–13	9.48–14	4.56–14	1.91–14	6.44–15	1.57–15	2.45–16	2.27–17
$11d_{3/2}$	1.14–11	6.39–12	3.60–12	2.03–12	1.14–12	6.37–13	3.53–13	1.90–13	9.58–14	4.23–14	1.50–14	4.06–15	7.92–16	9.91–17	7.09–18
$11d_{5/2}$	1.66–11	9.32–12	5.25–12	2.95–12	1.66–12	9.27–13	5.13–13	2.75–13	1.38–13	6.01–14	2.10–14	5.55–15	1.06–15	1.31–16	9.35–18
$11f_{5/2}$	1.72–11	9.68–12	5.45–12	3.06–12	1.72–12	9.59–13	5.26–13	2.75–13	1.29–13	4.95–14	1.45–14	3.24–15	5.43–16	6.21–17	4.25–18
$11f_{7/2}$	2.26–11	1.27–11	7.17–12	4.03–12	2.26–12	1.26–12	6.92–13	3.61–13	1.69–13	6.43–14	1.87–14	4.15–15	6.94–16	7.92–17	5.42–18

Table 1 (*continued*)

Shell	$\log_{10} T(K)$														
	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
$11g_{7/2}$	2.23–11	1.25–11	7.05–12	3.96–12	2.22–12	1.23–12	6.65–13	3.33–13	1.42–13	4.72–14	1.19–14	2.35–15	3.69–16	4.09–17	2.77–18
$11g_{9/2}$	2.76–11	1.55–11	8.73–12	4.91–12	2.75–12	1.53–12	8.23–13	4.12–13	1.76–13	5.81–14	1.46–14	2.88–15	4.52–16	5.00–17	3.38–18
$11h_{9/2}$	2.48–11	1.39–11	7.85–12	4.41–12	2.46–12	1.36–12	7.15–13	3.39–13	1.30–13	3.78–14	8.50–15	1.57–15	2.40–16	2.62–17	1.77–18
$11h_{11/2}$	2.96–11	1.66–11	9.36–12	5.26–12	2.94–12	1.62–12	8.52–13	4.03–13	1.55–13	4.49–14	1.01–14	1.86–15	2.84–16	3.11–17	2.09–18
$11i_{11/2}$	2.34–11	1.32–11	7.42–12	4.16–12	2.32–12	1.26–12	6.46–13	2.86–13	9.88–14	2.57–14	5.33–15	9.50–16	1.42–16	1.55–17	1.04–18
$11i_{13/2}$	2.72–11	1.53–11	8.61–12	4.83–12	2.69–12	1.46–12	7.49–13	3.31–13	1.14–13	2.97–14	6.17–15	1.10–15	1.65–16	1.79–17	1.21–18
$12s_{1/2}$	3.38–12	1.90–12	1.07–12	6.02–13	3.38–13	1.90–13	1.06–13	5.79–14	3.09–14	1.58–14	7.60–15	3.25–15	1.09–15	2.42–16	3.45–17
$12p_{1/2}$	3.58–12	2.02–12	1.14–12	6.39–13	3.59–13	2.01–13	1.12–13	6.20–14	3.32–14	1.68–14	7.58–15	2.79–15	7.53–16	1.30–16	1.38–17
$12p_{3/2}$	8.58–12	4.83–12	2.72–12	1.53–12	8.59–13	4.81–13	2.66–13	1.44–13	7.47–14	3.57–14	1.49–14	4.98–15	1.22–15	1.89–16	1.73–17
$12d_{3/2}$	9.07–12	5.11–12	2.87–12	1.62–12	9.08–13	5.08–13	2.81–13	1.51–13	7.55–14	3.31–14	1.17–14	3.16–15	6.17–16	7.80–17	5.73–18
$12d_{5/2}$	1.32–11	7.45–12	4.19–12	2.36–12	1.33–12	7.41–13	4.09–13	2.19–13	1.09–13	4.71–14	1.64–14	4.33–15	8.27–16	1.03–16	7.48–18
$12f_{5/2}$	1.38–11	7.77–12	4.37–12	2.46–12	1.38–12	7.70–13	4.22–13	2.20–13	1.03–13	3.92–14	1.15–14	2.55–15	4.28–16	4.89–17	3.34–18
$12f_{7/2}$	1.82–11	1.02–11	5.77–12	3.24–12	1.82–12	1.01–12	5.55–13	2.89–13	1.34–13	5.10–14	1.48–14	3.28–15	5.48–16	6.24–17	4.27–18
$12g_{7/2}$	1.82–11	1.02–11	5.76–12	3.24–12	1.81–12	1.01–12	5.43–13	2.71–13	1.16–13	3.82–14	9.60–15	1.90–15	2.98–16	3.31–17	2.23–18
$12g_{9/2}$	2.26–11	1.27–11	7.15–12	4.02–12	2.25–12	1.25–12	6.73–13	3.36–13	1.43–13	4.71–14	1.18–14	2.33–15	3.65–16	4.04–17	2.73–18
$12h_{9/2}$	2.10–11	1.18–11	6.65–12	3.74–12	2.09–12	1.15–12	6.06–13	2.86–13	1.10–13	3.19–14	7.16–15	1.32–15	2.02–16	2.21–17	1.49–18
$12h_{11/2}$	2.51–11	1.41–11	7.94–12	4.46–12	2.49–12	1.37–12	7.23–13	3.41–13	1.31–13	3.79–14	8.49–15	1.57–15	2.39–16	2.62–17	1.76–18
$12i_{11/2}$	2.11–11	1.19–11	6.68–12	3.75–12	2.09–12	1.14–12	5.82–13	2.57–13	8.88–14	2.30–14	4.79–15	8.53–16	1.28–16	1.39–17	9.36–19
$12i_{13/2}$	2.45–11	1.38–11	7.77–12	4.36–12	2.43–12	1.32–12	6.75–13	2.99–13	1.03–13	2.67–14	5.54–15	9.87–16	1.48–16	1.61–17	1.08–18
total	1.17–08	6.56–09	3.69–09	2.07–09	1.16–09	6.45–10	3.51–10	1.85–10	9.30–11	4.41–11	1.95–11	7.71–12	2.46–12	5.42–13	7.86–14