MODEL POTENTIALS FOR ALKALI METAL ATOMS AND Li-LIKE IONS

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In this article we present model potential parameters for alkali metal atoms Li to Cs and the Li isoelectronic sequence. Model potentials combined with discrete variable and finite element techniques allow an accurate and quick numerical method to compute atomic data in external fields even on small computers. Results obtained for binding energies, effective principal quantum numbers, and oscillator strengths for various transitions are compared with experimental values and other theoretical computations. © 1999 Academic Press

CONTENTS

I. INTRODUCTION AND THEORY

Over the years, model potentials [1] have been derived which were successfully used in different areas of atomic physics. For example, Dando et al. [2] computed, in quest of quantum chaos, classical properties like Poincaré surfaces-of-section and Liapunov exponents for some periodic trajectories of Li and Na in strong magnetic fields; Weibert et al. [3] carried out semiclassical computations of Rb in crossed magnetic and electric fields to gain a better understanding of crossed field experiments in the semiclassical parameter area [4]; González-Férez and Schweizer [5] computed atomic data for Ne VIII in strong magnetic fields to interpret some astronomical observations of the Am-Hercules system [6]; Faßbinder et al. [7] calculated the laser-induced wave packet propagation of Cs in an electric field and obtained a perfect agreement with the relevant experiments [8]; in [9] Schweizer and González-Férez presented atomic data for N V in electric fields for low temperature plasma diagnostics [10]; and in [11] these authors investigated a combination with complex coordinate rota-

tion [12] to uncover atomic resonances, to name only a few applications of our model potentials.

The basic idea of model potentials $V(r)$, r being the radial coordinate, is to simulate the multi-electron core interaction with the single valence electron by an analytic modification of the Coulomb potential, such that

$$\lim_{r \to \infty} \{V(r)\} = \lim_{r \to \infty} \left\{ -\frac{\tilde{Z}e^2}{r} \right\} \qquad (1)$$

$$\lim_{r \to 0} \{V(r)\} = \lim_{r \to 0} \left\{ -\frac{Ze^2}{r} \right\}, \qquad (2)$$

with e the electron charge; Z the atomic number; and $\tilde{Z}$ the ionization stage, which is 1 for neutral atoms, 2 for singly ionized atoms, and so forth.

The analytic form of the model potential function V_h we used is based on the work of Hanssen et al. [1]. The

TABLE A
Parameters a_i for the Model Potential [Eq. (4)]

Atom	Z	a_1	a_2	a_3	Range n	$\overline{\Delta E/E}$
Li	3	3.395	3.212	3.207	6–40	0.000070
					11–40	0.000063
Na	11	7.902	23.51	2.688	6–40	0.00068
K	19	3.491	10.591	1.730	6–40	0.0026
					11–40	0.0030
Rb	37	3.431	10.098	1.611	6–40	0.0073
					11–40	0.0067
Cs	55	3.294	11.005	1.509	6–40	0.0063
					11–40	0.0068

Note. $\overline{\Delta E/E}$ is the average of the magnitudes of the relative errors in the energy and range n is the range of the principal quantum number n over which the averaged error is computed, ΔE being the difference between our computation and experimental results. (The parameters for Na are from Hannsen et al. [1].)

Schrödinger equation for an effective one-particle atomic system in external fields reads (in atomic units)

$$\left[-\frac{\nabla^2}{2} + V_h(r) + V_f(\vec{r}) \right] \psi(\vec{r}) = E\psi(\vec{r}), \qquad (3)$$

where

$$V_h(r) = -\frac{1}{r}\left[\tilde{Z} + (Z - \tilde{Z})\exp(-a_1 r) + a_2 r \exp(-a_3 r) \right]; \qquad (4)$$

V_f is the potential function due to additional external fields, e.g., magnetic, electric, or van der Waals fields; and a_i ($i = 1, 2, 3$) are the model potential parameters. To uncover resonances the method of complex coordinate rotations could be used, as described in [11–13]. The model potential, given by Eq. (4), has the advantage that it has no additional higher order singularity than the Coulomb singularity. In many computations, singularities up to order -2 are lifted due to the integral density $r^2 \sin\theta \, dr \, d\theta \, d\phi$ in spherical coordinates r, θ, ϕ. To derive the model potential parameters a_i, we computed the eigensolutions of Eq. (3) as a function of the parameters a_i by a discrete-variable finite-element method [14]. The optimized parameters are then derived by a least-square fit to either experimental results (see, e.g., [15] for the alkali metal atoms) or theoretical results [16], as for some ions of the Li isoelectronic sequence accurate experimental results are not available. Although the parameters are fitted with respect to the energy, we found no differences in the wave function obtained by R-matrix quantum defect computations and that obtained by model potential computations for alkali atoms in strong external magnetic fields. Hence not only energies but also oscillator strengths obtained by (our own) R-matrix quantum defect and model potential computations are in excellent agreement.

In Table A we present the results thus derived for alkali metal atoms and in Table B for the Li isoelectronic sequence (except for the parameters a_i for Na in Table A, which are taken from Hannsen et al. [1]). The first column of both Tables labels the atom or ion; the next columns show the relevant properties and parameters of the model potential. The last columns in Table A show the averaged relative error in the energy $\Delta E/E$ and the range of the principal quantum number n for which this error has been computed. In Table B, the angular momentum varies from $0 \le l \le 2$ and the principal quantum number $n \le 10$. The parameters depend weakly on the energy and of course could be optimized to special energy ranges if necessary; note, however, that for strong magnetic and/or electric fields the principal quantum number is no longer conserved and hence wave functions of different principal quantum numbers would be mixed. In addition, the sets of parameters are not unique. We found additional sets which represent the energy quite well, but the listed ones are those with smallest averaged error in the energy, $\Delta E/E$.

In Tables I–VI of the data tables section, some results for energies, effective principal quantum numbers, dipole strengths, and oscillator strengths for various transitions for alkali metal atoms and the Li isoelectronic sequence computed with the parameter sets in Tables A and B are compared with experimental values and other theoretical computations. Because the potential $V_h(r)$ differs from the pure Coulomb term only at short distances, the energy eigenvalues can still be written in the form $-\tilde{Z}/(2n_{\text{eff}}^2)$ with $n_{\text{eff}} = n - \mu_l$ the effective principal quantum number, n the principal quantum number, and μ_l the quantum defect. The dipole strength d is given by

$$d_{\alpha,\beta}^{(q)} = |\langle \alpha | r^{(q)} | \beta \rangle|^2, \qquad (5)$$

TABLE B
Parameters a_i for the Model Potential [Eq. (4)]

Ion	Z	$\tilde{Z}$	a_1	a_2	a_3	$\overline{\Delta E/E}$
Li I	3	1	3.395	3.212	3.207	0.00007
Be II	4	2	4.733	4.804	4.814	0.00065
B III	5	3	6.152	6.290	6.300	0.00050
C IV	6	4	7.655	7.654	7.674	0.00036
N V	7	5	9.100	9.109	9.108	0.00032
O VI	8	6	10.467	10.449	10.552	0.00030
F VII	9	7	11.939	11.990	11.990	0.00027
Ne VIII	10	8	13.246	12.941	13.341	0.00025

Note. $\overline{\Delta E/E}$ is the averaged relative error over all computed eigenstates up to principal quantum number $n = 10$, ΔE being the difference between our computation and experimental results or the computations of [16].

where α, β denote the sets of quantum numbers characterizing the initial and final states, respectively, and $r^{(q)} = \sqrt{4\pi/3}\, r Y_{1q}$ are the spherical components of the dipole operator. As the dipole strengths for the three spherical components are equal for s–p transitions, we omit the spherical index (q) for these transitions. A common way to express the strengths of transitions is to use the oscillator strength, which we computed in its length form (in a.u.) by

$$f_{\alpha,\beta}^{(q)} = 2m(E_\alpha - E_\beta)d_{\alpha,\beta}^{(q)}, \qquad (6)$$

where again α, β are the set of relevant quantum numbers, E_α, E_β are the corresponding energies, and m is the reduced mass. Equivalent definitions of the oscillator strength are given by the velocity and the acceleration forms. For more details see, for example, [17].

In conclusion, analytical model potentials are useful in various areas of atomic physics and allow effective computations on small computers even in external magnetic and electric fields and in energy areas in which the atomic system becomes non-integrable and hence perturbation methods are no longer applicable. Further results, especially those in external electric and magnetic fields, as well as the program codes, are available on request.

References

1. J. Hannsen, R. McCarrol, and P. Valiron, J. Phys. B **12,** 899 (1979)

2. P. Dando, T. S. Monteiro, W. Jans, and W. Schweizer, Prog. Theor. Phys. Suppl. **116,** 403 (1994)

3. K. Weibert, J. Main, and G. Wunner, submitted for publication

4. G. Raithel, M. Fauth, and H. Walther, Phys. Rev. A **44,** 1898 (1991)

5. R. González-Férez and W. Schweizer, preprint (1998)

6. C. Mauche, private communication (1997)

7. P. Faßbinder, W. Schweizer, and T. Uzer, Phys. Rev. A **56,** 3626 (1997)

8. M. L. Naudeau, C. I. Sukenik, and P. H. Bucksbaum, Phys. Rev. A **56,** 636 (1997)

9. W. Schweizer and R. González-Férez, SFB191 Report 55-C6-98 (1998)

10. I. P. Vinogradov, B. Jettkant, D. Meyer, and K. Wiesemann, J. Phys. D **27,** 1207 (1994)

11. R. González-Férez and W. Schweizer, Prog. Theor. Chem., in press

12. Y. K. Ho, Phys. Rep. **99,** 1 (1983)

13. I. Seipp, K. T. Taylor, and W. Schweizer, J. Phys. B **29,** 1 (1998)

14. W. Schweizer and P. Faßbinder, Comput. Phys. **11,** 641 (1997)

15. T. F. Gallagher, *Rydberg Atoms* (Cambridge Univ. Press, Cambridge, UK, 1994)

16. G. Peach, H. E. Saraph, and M. J. Seaton, J. Phys. B **21,** 3669 (1988)

17. R. C. Cowan, *The Theory of Atomic Structure and Spectra* (Univ. of California Press, Berkeley, 1981)

18. C. Barrientos and I. Martin, Phys. Rev. A **42,** 432 (1990)

19. G. A. Martin and W. L. Wiese, J. Phys. Chem. Ref. Data **5,** 537 (1976)

20. C. E. Moore, *Atomic Energy Levels,* Natl. Bur. Stand. (USA) Circ. No. 467 (U.S. GPO, Washington, DC, 1949)

21. B. Kundu, D. Ray, and P. K. Mukherjee, Phys. Rev. A **34,** 62 (1986)

22. R. P. McEachran and M. Szulkin, J. Phys. B **16,** 3125 (1983)

23. J. C. Weisheit and A. Dalgarno, Chem. Phys. Lett. **9,** 517 (1971)

24. C. Froese-Fischer, Can. J. Phys. **54,** 1465 (1976)

25. L. Qu, Z. Wang, and B. Li, J. Phys. B **31,** 3601 (1998)

26. E. Biemont, Astron. Astrophys. Suppl. **27,** 489 (1977)

27. J. Heldt and G. Leuchs, Z. Phys. A **291,** 11 (1979)

28. C. Jacques, E. J. Knystautas, R. Drouin, and H. G. Berry, Can. J. Phys. **58,** 1093 (1980)

29. P. H. Heckmann, E. Trabert, H. Winter, F. Hannebauer, H. H. Bukow, and H. V. Buttlar, Phys. Lett. **57A,** 126 (1976)

TABLE I.   **Outer Electron Binding Energies and Dipole Strengths for Rydberg Transitions in Alkali Metal Atoms**

Li: $3s \rightarrow np$ and $3p \rightarrow ns$, $n = 6$–40
Na: $4s \rightarrow np$ and $4p \rightarrow ns$, $n = 5$–40
K: $5s \rightarrow np$ and $5p \rightarrow ns$, $n = 6$–40
Rb: $6s \rightarrow np$ and $6p \rightarrow ns$, $n = 7$–40
Cs: $7s \rightarrow np$ and $7p \rightarrow ns$, $n = 8$–40

       In this Table, each data block refers to the same initial state and alkali metal atom. The label for the state is abbreviated by single-electron notations, for example, $3s$ for Li stands for $1s^2 3s$. The one-electron binding energy of the initial state (in a.u.) is given at the head of each data block.

n	Final state principal quantum number.
E^{MP}	Final state one-electron binding energy referenced to the He-like $1s^2$ core, in a.u., obtained by the model potential computations.
d	Dipole strength [Eq. (5)], in a.u.
x	Exponent in the expression $d \times 10^x$, so that for the listed case $d \cdot 10^x = 9.84535$ and $x = -3$, the value of d is equal to 0.00984535.
E^{QD}	Final state one-electron binding energy in a.u., from quantum defect calculations with the quantum defects of Ref. [15].

TABLE II.   **Outer Electron Binding Energies and Dipole Strengths for $3s \rightarrow np$ ($n = 4$–10) Transitions in Li-like Ions Be II to Ne VIII**

TABLE III.   **Outer Electron Binding Energies and Dipole Strengths for $3p \rightarrow ns$ ($n = 4$–10) Transitions in Li-like Ions Be II to Ne VIII**

       In Tables II and III, the data blocks are for the individual ions, and the initial state one-electron binding energy is given in the first line below the column headings. The headings for the data are as in Table I.

TABLE IV.   **Comparison of Absorption Oscillator Strengths for Several Transitions in Li-like Ions Li I to Ne VIII with Results of Other Works**

$2s \rightarrow 4p$ Transition
$2s \rightarrow 7p$ Transition
$2p \rightarrow 3d$ Transition
$2p \rightarrow nd$ ($n = 4$–9) Transitions

This work	Present calculation using model potential.
min [18]	Range of oscillator strength values from Ref. [18].
max [18]	
[19]	Oscillator strength from Ref. [19].
Exp.	Experimental value, followed by the reference from which it is taken.

TABLE V.   **Comparison of Some Quantum Defects for Li I and C IV Obtained by Different Computations with Experimental Results**

μ_l^{comp}	Quantum defect computed in this work.
μ_l^{exp}	Quantum defect from experiment.
$\delta\mu_l = \mu_l^{comp} - \mu_l^{exp}$	
EP[16]	Results in Ref. [16] computed with an empirical potential.
CC[16]	Results in Ref. [16] obtained by close-coupling computations.

TABLE VI.   **Comparison of Transition Energies, Absorption Oscillator Strengths, and Effective Quantum Numbers for $3s \rightarrow np$ ($n = 3$–7) Transitions in Na with Experiment and Other Calculations**

$E_{3s,np}$	Energy for the $3s \rightarrow np$ transition.
n_{eff}	Effective quantum number for the np state.
$f_{3s,np}$	Oscillator strength for the $3s \rightarrow np$ transition.

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

Li: Transitions from the 3s to np states. Binding energy of the initial state is -0.0741877176

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
6	-0.014110542	9.84535	-3	-0.014106892
7	-0.010344126	6.70833	-3	-0.010341701
8	-0.007906499	4.62718	-3	-0.007904824
9	-0.006238936	3.29052	-3	-0.006237737
10	-0.005048220	2.41248	-3	-0.005047335
11	-0.004168478	1.81733	-3	-0.004167806
12	-0.003500150	1.40144	-3	-0.003499629
13	-0.002980550	1.10273	-3	-0.002980139
14	-0.002568613	8.82922	-4	-0.002568283
15	-0.002236527	7.17715	-4	-0.002236258
16	-0.001964912	5.91208	-4	-0.001964690
17	-0.001739931	4.92728	-4	-0.001739745
18	-0.001551489	4.14937	-4	-0.001551332
19	-0.001392081	3.52683	-4	-0.001391947
20	-0.001256035	3.02277	-4	-0.001255921
21	-0.001139000	2.61032	-4	-0.001138901
22	-0.001037592	2.26959	-4	-0.001037506
23	-0.000949148	1.98566	-4	-0.000949072
24	-0.000871548	1.74717	-4	-0.000871481
25	-0.000803090	1.54538	-4	-0.000803031
26	-0.000742391	1.37350	-4	-0.000742339
27	-0.000688323	1.22620	-4	-0.000688277
28	-0.000639954	1.09922	-4	-0.000639912
29	-0.000596509	9.89186	-5	-0.000596472
30	-0.000557343	8.93361	-5	-0.000557309
31	-0.000521911	8.09523	-5	-0.000521881
32	-0.000489754	7.35855	-5	-0.000489726
33	-0.000460480	6.70861	-5	-0.000460454
34	-0.000433754	6.13301	-5	-0.000433730
35	-0.000409289	5.62115	-5	-0.000409267
36	-0.000386837	5.16519	-5	-0.000386817
37	-0.000366183	4.75701	-5	-0.000366165
38	-0.000347140	4.39074	-5	-0.000347123
39	-0.000329545	4.06113	-5	-0.000329529
40	-0.000313254	3.76369	-5	-0.000313240

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
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Li: Transitions from the 3p to ns states. Binding energy of the initial state is -0.05723931885

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
6	-0.015945303	3.20932	-1	-0.015946323
7	-0.011478611	1.39138	-1	-0.011478979
8	-0.008656353	7.46404	-2	-0.008656488
9	-0.006760173	4.53424	-2	-0.006760216
10	-0.005425110	2.98824	-2	-0.005425116
11	-0.004449770	2.08609	-2	-0.004449761
12	-0.003715632	1.52020	-2	-0.003715618
13	-0.003149253	1.14535	-2	-0.003149237
14	-0.002703156	8.86248	-3	-0.002703141
15	-0.002345545	7.00909	-3	-0.002345530
16	-0.002054475	5.64546	-3	-0.002054462
17	-0.001814406	4.61819	-3	-0.001814395
18	-0.001614084	3.82862	-3	-0.001614073
19	-0.001445194	3.21113	-3	-0.001445184
20	-0.001301489	2.72088	-3	-0.001301480
21	-0.001178200	2.32645	-3	-0.001178192
22	-0.001071634	2.00534	-3	-0.001071627
23	-0.000978898	1.74116	-3	-0.000978892
24	-0.000897700	1.52175	-3	-0.000897694
25	-0.000826200	1.33796	-3	-0.000826195
26	-0.000762915	1.18279	-3	-0.000762910
27	-0.000706632	1.05085	-3	-0.000706628
28	-0.000656355	9.37939	-4	-0.000656351
29	-0.000611259	8.40722	-4	-0.000611256
30	-0.000570656	7.56553	-4	-0.000570653
31	-0.000533968	6.83305	-4	-0.000533965
32	-0.000500708	6.19256	-4	-0.000500705
33	-0.000470461	5.63000	-4	-0.000470459
34	-0.000442874	5.13383	-4	-0.000442872
35	-0.000417645	4.69450	-4	-0.000417643
36	-0.000394511	4.30407	-4	-0.000394510
37	-0.000373248	3.95590	-4	-0.000373247
38	-0.000353659	3.64442	-4	-0.000353657
39	-0.000335572	3.36489	-4	-0.000335571
40	-0.000318838	3.11331	-4	-0.000318837

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Na: Transitions from the 4s to np states. Binding energy of the initial state is −0.071672772557

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
5	-0.029244687	4.43790	-1	-0.029202148
6	-0.018948120	7.08318	-2	-0.018922609
7	-0.013271282	2.29465	-2	-0.013255181
8	-0.009811422	1.03068	-2	-0.009800727
9	-0.007547675	5.56568	-3	-0.007540251
10	-0.005985918	3.37683	-3	-0.005980573
11	-0.004863214	2.21866	-3	-0.004859246
12	-0.004029153	1.54414	-3	-0.004026129
13	-0.003392633	1.12245	-3	-0.003390278
14	-0.002895855	8.44090	-4	-0.002893987
15	-0.002500715	6.52276	-4	-0.002499209
16	-0.002181264	5.15424	-4	-0.002180032
17	-0.001919335	4.14944	-4	-0.001918315
18	-0.001701903	3.39371	-4	-0.001701049
19	-0.001519431	2.81355	-4	-0.001518709
20	-0.001364806	2.36022	-4	-0.001364191
21	-0.001232638	2.00053	-4	-0.001232109
22	-0.001118779	1.71123	-4	-0.001118321
23	-0.001019998	1.47576	-4	-0.001019598
24	-0.000933744	1.28204	-4	-0.000933394
25	-0.000857986	1.12113	-4	-0.000857677
26	-0.000791087	9.86312	-5	-0.000790813
27	-0.000731718	8.72462	-5	-0.000731474
28	-0.000678790	7.75627	-5	-0.000678572
29	-0.000631404	6.92721	-5	-0.000631208
30	-0.000588812	6.21309	-5	-0.000588636
31	-0.000550389	5.59443	-5	-0.000550229
32	-0.000515607	5.05598	-5	-0.000515463
33	-0.000484022	4.58483	-5	-0.000483890
34	-0.000455252	4.17079	-5	-0.000455132
35	-0.000428973	3.80543	-5	-0.000428863
36	-0.000404906	3.48176	-5	-0.000404805
37	-0.000382808	3.19396	-5	-0.000382716
38	-0.000362472	2.93705	-5	-0.000362386
39	-0.000343714	2.70734	-5	-0.000343635
40	-0.000326375	2.50097	-5	-0.000326302

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for Rydberg Transitions in Alkali Metal Atoms
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Na: Transitions from the 4p to ns states. Binding energy of the initial state is -0.051021971037

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
5	-0.037629033	3.49848	1	-.037583412
6	-0.023154986	1.25254	0	-.023132069
7	-0.015675380	3.10889	-1	-.015662325
8	-0.011312385	1.28956	-1	-.011304272
9	-0.008546903	6.76480	-2	-.008541528
10	-0.006684351	4.05639	-2	-.006680611
11	-0.005370450	2.65137	-2	-.005367745
12	-0.004409081	1.84068	-2	-.004407063
13	-0.003684535	1.33613	-2	-.003682989
14	-0.003124956	1.00381	-2	-.003123747
15	-0.002683814	7.75085	-3	-.002682850
16	-0.002329898	6.12003	-3	-.002329117
17	-0.002041637	4.92318	-3	-.002040998
18	-0.001803746	4.02337	-3	-.001803213
19	-0.001605134	3.33286	-3	-.001604687
20	-0.001437608	2.79356	-3	-.001437229
21	-0.001295004	2.36584	-3	-.001294679
22	-0.001172612	2.02203	-3	-.001172332
23	-0.001066785	1.74233	-3	-.001066542
24	-0.000974664	1.51237	-3	-.000974452
25	-0.000893980	1.32147	-3	-.000893793
26	-0.000822915	1.16163	-3	-.000822751
27	-0.000759999	1.02674	-3	-.000759853
28	-0.000704032	9.12086	-4	-.000703902
29	-0.000654027	8.13987	-4	-.000653911
30	-0.000609167	7.29546	-4	-.000609062
31	-0.000568768	6.56453	-4	-.000568674
32	-0.000532259	5.92857	-4	-.000532174
33	-0.000499156	5.37255	-4	-.000499078
34	-0.000469048	4.88425	-4	-.000468977
35	-0.000441583	4.45363	-4	-.000441518
36	-0.000416462	4.07237	-4	-.000416403
37	-0.000393426	3.73356	-4	-.000393317
38	-0.000372249	3.43147	-4	-.000372199
39	-0.000352737	3.16124	-4	-.000352691
40	-0.000334720	2.91874	-4	-.000334677

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

K: Transitions from the 5s to np states. Binding energy of the initial state is
-0.063632155002

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
6	-0.027369987	4.20579	-1	-0.027364784
7	-0.017949598	6.07747	-2	-0.017941188
8	-0.012678342	1.86319	-2	-0.012671445
9	-0.009431208	8.07991	-3	-0.009426028
10	-0.007289534	4.26012	-3	-0.007285674
11	-0.005802747	2.54129	-3	-0.005799839
12	-0.004728593	1.64914	-3	-0.004726365
13	-0.003927342	1.13718	-3	-0.003925605
14	-0.003313784	8.20794	-4	-0.003312408
15	-0.002833554	6.13859	-4	-0.002832448
16	-0.002450639	4.72314	-4	-0.002449738
17	-0.002140413	3.71934	-4	-0.002139670
18	-0.001885577	2.98596	-4	-0.001884957
19	-0.001673686	2.43662	-4	-0.001673164
20	-0.001495607	2.01634	-4	-0.001495163
21	-0.001344508	1.68888	-4	-0.001344128
22	-0.001215204	1.42967	-4	-0.001214876
23	-0.001103694	1.22164	-4	-0.001103409
24	-0.001006858	1.05260	-4	-0.001006609
25	-0.000922229	9.13740	-5	-0.000922010
26	-0.000847838	7.98551	-5	-0.000847645
27	-0.000782099	7.02147	-5	-0.000781927
28	-0.000723720	6.20816	-5	-0.000723566
29	-0.000671641	5.51697	-5	-0.000671504
30	-0.000624988	4.92564	-5	-0.000624865
31	-0.000583032	4.41662	-5	-0.000582921
32	-0.000545164	3.97597	-5	-0.000545063
33	-0.000510868	3.59249	-5	-0.000510777
34	-0.000479710	3.25716	-5	-0.000479627
35	-0.000451318	2.96259	-5	-0.000451242
36	-0.000425374	2.70273	-5	-0.000425305
37	-0.000401605	2.47259	-5	-0.000401541
38	-0.000379773	2.26801	-5	-0.000379714
39	-0.000359675	2.08553	-5	-0.000359620
40	-0.000341131	1.92221	-5	-0.000341080

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

K: Transitions from the 5p to ns states.   Binding energy of the initial state is −0.046868747131

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
6	-0.034439066	3.88033	1	-0.034442841
7	-0.021581072	1.60231	0	-0.021577148
8	-0.014786886	4.07852	-1	-0.014783022
9	-0.010762764	1.70928	-1	-0.010759782
10	-0.008183622	9.01972	-2	-0.008181403
11	-0.006431877	5.43051	-2	-0.006430218
12	-0.005187945	3.56051	-2	-0.005186686
13	-0.004272912	2.47801	-2	-0.004271939
14	-0.003580256	1.80254	-2	-0.003579492
15	-0.003043341	1.35666	-2	-0.003042731
16	-0.002618744	1.04919	-2	-0.002618250
17	-0.002277187	8.29594	-3	-0.002276782
18	-0.001998346	6.68194	-3	-0.001998011
19	-0.001767756	5.46685	-3	-0.001767474
20	-0.001574892	4.53326	-3	-0.001574654
21	-0.001411953	3.80328	-3	-0.001411750
22	-0.001273052	3.22374	-3	-0.001272877
23	-0.001153684	2.75743	-3	-0.001153533
24	-0.001050351	2.37775	-3	-0.001050219
25	-0.000960303	2.06532	-3	-0.000960188
26	-0.000881359	1.80577	-3	-0.000881257
27	-0.000811763	1.58829	-3	-0.000811673
28	-0.000750097	1.40462	-3	-0.000750017
29	-0.000695200	1.24841	-3	-0.000695128
30	-0.000646116	1.11468	-3	-0.000646052
31	-0.000602053	9.99497	-4	-0.000601995
32	-0.000562348	8.99743	-4	-0.000562296
33	-0.000526446	8.12909	-4	-0.000526398
34	-0.000493875	7.36952	-4	-0.000493831
35	-0.000464235	6.70215	-4	-0.000464196
36	-0.000437187	6.11335	-4	-0.000437150
37	-0.000412435	5.59184	-4	-0.000412401
38	-0.000389727	5.12824	-4	-0.000389696
39	-0.000368844	4.71470	-4	-0.000368816
40	-0.000349595	4.34461	-4	-0.000349570

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

Rb: Transitions from the 6s to np states. Binding energy of the initial state is
-0.062350204972

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
7	-0.026947209	4.70788	-1	-.026540934
8	-0.017720945	7.11753	-2	-.017511785
9	-0.012541179	2.24999	-2	-.012418315
10	-0.009342618	9.96962	-3	-.009263794
11	-0.007229063	5.33882	-3	-.007175292
12	-0.005759659	3.22170	-3	-.005721281
13	-0.004696821	2.10907	-3	-.004668451
14	-0.003903249	1.46424	-3	-.003881680
15	-0.003295083	1.06256	-3	-.003278300
16	-0.002818751	7.98107	-4	-.002805435
17	-0.002438721	6.16246	-4	-.002427980
18	-0.002130678	4.86691	-4	-.002121888
19	-0.001877522	3.91678	-4	-.001870238
20	-0.001666946	3.20278	-4	-.001660843
21	-0.001489910	2.65501	-4	-.001484746
22	-0.001339651	2.22719	-4	-.001335243
23	-0.001211028	1.88784	-4	-.001207236
24	-0.001100079	1.61498	-4	-.001096792
25	-0.001003707	1.39292	-4	-.001000840
26	-0.000919466	1.21024	-4	-.000916951
27	-0.000845403	1.05851	-4	-.000843184
28	-0.000779940	9.31383	-5	-.000777973
29	-0.000721798	8.24006	-5	-.000720045
30	-0.000669922	7.32798	-5	-.000668355
31	-0.000623445	6.54503	-5	-.000622037
32	-0.000581642	5.87142	-5	-.000580373
33	-0.000543907	5.28788	-5	-.000542758
34	-0.000509728	4.77955	-5	-.000508686
35	-0.000478673	4.33515	-5	-.000477724
36	-0.000450371	3.94439	-5	-.000449505
37	-0.000424508	3.59951	-5	-.000423715
38	-0.000400809	3.29393	-5	-.000400082
39	-0.000379042	3.02222	-5	-.000378373
40	-0.000359001	2.77970	-5	-.000358384

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

Rb: Transitions from the 6p to ns states. Binding energy of the initial state is −0.045955671767

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
7	-0.033904257	4.08278	1	-0.033501308
8	-0.021310338	1.66316	0	-0.021138630
9	-0.014631648	4.22593	-1	-0.014538205
10	-0.010665721	1.77048	-1	-0.010608185
11	-0.008118996	9.34319	-2	-0.008080797
12	-0.006386709	5.62626	-2	-0.006359984
13	-0.005155152	3.68967	-2	-0.005135704
14	-0.004248358	2.56850	-2	-0.004233760
15	-0.003561399	1.86878	-2	-0.003550161
16	-0.003028547	1.40683	-2	-0.003019712
17	-0.002606925	1.08820	-2	-0.002599854
18	-0.002267597	8.60608	-3	-0.002261849
19	-0.001990458	6.93297	-3	-0.001985723
20	-0.001761189	5.67318	-3	-0.001757243
21	-0.001569368	4.70508	-3	-0.001566045
22	-0.001407261	3.94800	-3	-0.001404437
23	-0.001269034	3.34686	-3	-0.001266613
24	-0.001150217	2.86310	-3	-0.001148126
25	-0.001047338	2.46916	-3	-0.001045520
26	-0.000957669	2.14496	-3	-0.000956079
27	-0.000879042	1.87559	-3	-0.000877643
28	-0.000809715	1.64986	-3	-0.000808477
29	-0.000748278	1.45921	-3	-0.000747178
30	-0.000693576	1.29704	-3	-0.000692594
31	-0.000644661	1.15819	-3	-0.000643781
32	-0.000600744	1.03859	-3	-0.000599952
33	-0.000561167	9.35006	-4	-0.000560451
34	-0.000525375	8.44822	-4	-0.000524727
35	-0.000492902	7.65938	-4	-0.000492313
36	-0.000463349	6.96613	-4	-0.000462812
37	-0.000436376	6.35457	-4	-0.000435885
38	-0.000411692	5.81281	-4	-0.000411242
39	-0.000389045	5.33118	-4	-0.000388631
40	-0.000368216	4.90145	-4	-0.000367835

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

Cs: Transitions from the 7s to np states. Binding energy of the initial state is -0.058031971937

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
8	-0.026014423	3.57679	-1	-0.025763161
9	-0.017216631	4.47517	-2	-0.017071718
10	-0.012238368	1.25349	-2	-0.012147956
11	-0.009146800	5.10761	-3	-0.009086883
12	-0.007095235	2.57477	-3	-0.007053597
13	-0.005664196	1.48563	-3	-0.005634139
14	-0.004626358	9.40022	-4	-0.004603976
15	-0.003849768	6.35648	-4	-0.003832666
16	-0.003253539	4.51794	-4	-0.003240184
17	-0.002785840	3.33763	-4	-0.002775217
18	-0.002412209	2.54262	-4	-0.002403622
19	-0.002109008	1.98601	-4	-0.002101969
20	-0.001859584	1.58371	-4	-0.001853743
21	-0.001651930	1.28510	-4	-0.001647031
22	-0.001477214	1.05842	-4	-0.001473065
23	-0.001328821	8.82970	-5	-0.001325276
24	-0.001201716	7.44893	-5	-0.001198664
25	-0.001092013	6.34622	-5	-0.001089367
26	-0.000996675	5.45414	-5	-0.000994366
27	-0.000913299	4.72412	-5	-0.000911271
28	-0.000839963	4.12057	-5	-0.000838174
29	-0.000775119	3.61694	-5	-0.000773532
30	-0.000717505	3.19318	-5	-0.000716090
31	-0.000666083	2.83389	-5	-0.000664817
32	-0.000619997	2.52714	-5	-0.000618860
33	-0.000578535	2.26360	-5	-0.000577509
34	-0.000541096	2.03583	-5	-0.000540168
35	-0.000507178	1.83792	-5	-0.000506336
36	-0.000476351	1.66510	-5	-0.000475585
37	-0.000448252	1.51347	-5	-0.000447552
38	-0.000422568	1.37986	-5	-0.000421928
39	-0.000399030	1.26165	-5	-0.000398442
40	-0.000377405	1.15667	-5	-0.000376864

TABLE I. Outer Electron Binding Energies and Dipole Strengths
for Rydberg Transitions in Alkali Metal Atoms
See page 37 for Explanation of Tables

Cs: Transitions from the 7p to ns states. Binding energy of the initial state is −0.043929778197

n	E^{MP}	$d \cdot 10^x$	x	E^{QD}
8	-0.032136702	4.12139	1	-0.032292871
9	-0.020418919	1.91416	0	-0.020483659
10	-0.014120583	4.97530	-1	-0.014153186
11	-0.010345959	2.10263	-1	-0.010364632
12	-0.007905803	1.11475	-1	-0.007917501
13	-0.006237530	6.73292	-2	-0.006245354
14	-0.005046721	4.42501	-2	-0.005052220
15	-0.004167090	3.08561	-2	-0.004171107
16	-0.003498928	2.24813	-2	-0.003501955
17	-0.002979496	1.69439	-2	-0.002981836
18	-0.002567711	1.31197	-2	-0.002569558
19	-0.002235755	1.03850	-2	-0.002237239
20	-0.001964250	8.37265	-3	-0.001965462
21	-0.001739361	6.85612	-3	-0.001740364
22	-0.001550996	5.68982	-3	-0.001551835
23	-0.001391653	4.77709	-3	-0.001392362
24	-0.001255662	4.05187	-3	-0.001256267
25	-0.001138673	3.46791	-3	-0.001139193
26	-0.001037304	2.99212	-3	-0.001037754
27	-0.000948892	2.60034	-3	-0.000949285
28	-0.000871321	2.27468	-3	-0.000871666
29	-0.000802887	2.00164	-3	-0.000803192
30	-0.000742210	1.77094	-3	-0.000742480
31	-0.000688161	1.57464	-3	-0.000688401
32	-0.000639807	1.40649	-3	-0.000640022
33	-0.000596377	1.26161	-3	-0.000596570
34	-0.000557223	1.13607	-3	-0.000557397
35	-0.000521802	1.02676	-3	-0.000521960
36	-0.000489654	9.31105	-4	-0.000489797
37	-0.000460388	8.47018	-4	-0.000460519
38	-0.000433670	7.72826	-4	-0.000433789
39	-0.000409212	7.07082	-4	-0.000409321
40	-0.000386766	6.48606	-4	-0.000386866

TABLE II. Outer Electron Binding Energies and Dipole Strengths for $3s \rightarrow np$ ($n = 4$–10)
Transitions in Li-like Atoms Be II to Ne VIII
See page 37 for Explanation of Tables

Ion	np	E^{MP}	$d \cdot 10^x$	x	E^{QD}
Be II	(3s	-0.2674025)			
	4p	-0.128166	2.42468	-1	-0.128013
	5p	-0.081633	7.69522	-2	-0.081548
	6p	-0.056504	3.46007	-2	-0.056453
	7p	-0.041414	1.88272	-2	-0.041381
	8p	-0.031651	1.15017	-2	-0.031629
	9p	-0.024973	7.59063	-3	-0.024957
	10p	-0.020205	5.29519	-3	-0.020194
B III	(3s	-0.5729813)			
	4p	-0.287581	2.55945	-1	-0.287291
	5p	-0.183258	6.55604	-2	-0.183098
	6p	-0.126889	2.73825	-2	-0.126794
	7p	-0.093028	1.43695	-2	-0.092966
	8p	-0.071111	8.59494	-3	-0.071069
	9p	-0.056116	5.59736	-3	-0.056087
	10p	-0.045419	3.84814	-3	-0.045387
C IV	(3s	-0.9896254)			
	4p	-0.509797	2.14165	-1	-0.509380
	5p	-0.325036	4.96383	-2	-0.324807
	6p	-0.225141	2.00143	-2	-0.225005
	7p	-0.165105	1.03214	-2	-0.165017
	8p	-0.126233	6.11178	-3	-0.126174
	9p	-0.099631	3.95428	-3	-0.099590
	10p	-0.080631	2.72130	-3	-0.080601
N V	(3s	-1.518041)			
	4p	-0.794688	1.71200	-1	-0.794140
	5p	-0.506903	3.74417	-2	-0.506605
	6p	-0.351222	1.47904	-2	-0.351042
	7p	-0.257623	7.55015	-3	-0.257507
	8p	-0.197002	4.44456	-3	-0.196923
	9p	-0.155507	2.86490	-3	-0.155451
	10p	-0.125865	1.96677	-3	-0.125824

TABLE II. Outer Electron Binding Energies and Dipole Strengths for $3s \rightarrow np$ ($n = 4$–10)
Transitions in Li-like Atoms Be II to Ne VIII
See page 37 for Explanation of Tables

Ion	np	E^{MP}	$d \cdot 10^x$	x	E^{QD}
O VI	(3s	-2.157821)			
	4p	-1.142177	1.37379	-1	-1.141485
	5p	-0.728820	2.88978	-2	-0.728440
	6p	-0.505111	1.12600	-2	-0.504885
	7p	-0.370567	5.70933	-3	-0.370420
	8p	-0.283408	3.34776	-3	-0.283308
	9p	-0.223738	2.15254	-3	-0.223667
	10p	-0.181105	1.47522	-3	-0.181053
F VII	(3s	-2.908792)			
	4p	-1.552226	1.11788	-1	-1.551400
	5p	-0.990769	2.28609	-2	-0.990310
	6p	-0.686794	8.81996	-3	-0.686520
	7p	-0.503931	4.45031	-3	-0.503755
	8p	-0.385446	2.60213	-3	-0.385325
	9p	-0.304319	1.67010	-3	-0.304233
	10p	-0.246348	1.14319	-3	-0.246286
Ne VIII	(3s	-3.770285)			
	4p	-2.024793	9.25393	-2	-2.023845
	5p	-1.292725	1.85126	-2	-1.292205
	6p	-0.896260	7.08751	-3	-0.895945
	7p	-0.657705	3.56258	-3	-0.657500
	8p	-0.503111	2.07849	-3	-0.502970
	9p	-0.397247	1.33215	-3	-0.397148
	10p	-0.321593	9.10975	-5	-0.321521

TABLE III. Outer Electron Binding Energies and Dipole Strengths for $3p \rightarrow ns$ ($n = 4$–10) Transitions in Li-like Atoms Be II to Ne VIII

See page 37 for Explanation of Tables

Ion	ns	E^{MP}	$d \cdot 10^x$	x	E^{QD}
Be II	(3p	−0.2295804)			
	4s	−0.143267	2.34837	0	−0.143051
	5s	−0.089133	2.32217	−1	−0.089017
	6s	−0.060761	7.12111	−2	−0.060693
	7s	−0.044059	3.21757	−2	−0.044017
	8s	−0.033406	1.76505	−2	−0.033377
	9s	−0.026196	1.08720	−2	−0.026176
	10s	−0.021092	7.23309	−3	−0.021077
B III	(3p	−0.5147909)			
	4s	−0.311031	7.29987	−1	−0.310722
	5s	−0.194969	8.38437	−2	−0.194797
	6s	−0.133561	2.67217	−2	−0.133459
	7s	−0.097184	1.22791	−2	−0.097119
	8s	−0.073874	6.79852	−3	−0.073830
	9s	−0.058045	4.21240	−3	−0.058014
	10s	−0.046814	2.80568	−3	−0.046786
C IV	(3p	−0.9118549)			
	4s	−0.541327	3.26796	−1	−0.541160
	5s	−0.340837	4.05611	−2	−0.340726
	6s	−0.234164	1.32000	−2	−0.234093
	7s	−0.170736	6.12219	−3	−0.170688
	8s	−0.129980	3.40727	−3	−0.129947
	9s	−0.102250	2.11802	−3	−0.102227
	10s	−0.082533	1.41796	−3	−0.082516
N V	(3p	−1.420442)			
	4s	−0.834412	1.79674	−1	−0.834240
	5s	−0.526857	2.33454	−2	−0.526730
	6s	−0.362635	7.69394	−3	−0.362552
	7s	−0.264752	3.58864	−3	−0.264696
	8s	−0.201751	2.00355	−3	−0.201711
	9s	−0.158828	1.24797	−3	−0.158800
	10s	−0.128278	8.36700	−4	−0.128257

TABLE III. Outer Electron Binding Energies and Dipole Strengths for $3p \rightarrow ns$ $(n = 4-10)$
Transitions in Li-like Atoms Be II to Ne VIII
See page 37 for Explanation of Tables

Ion	ns	E^{MP}	$d \cdot 10^x$	x	E^{QD}
O VI	(3p	-2.040378)			
	4s	-1.190116	1.11789	-1	-1.189880
	5s	-0.752942	1.49776	-2	-0.752775
	6s	-0.518921	4.97878	-3	-0.518810
	7s	-0.379202	2.33127	-3	-0.379138
	8s	-0.289163	1.30439	-3	-0.289111
	9s	-0.227764	8.13605	-4	-0.227727
	10s	-0.184031	5.46007	-4	-0.184003
F VII	(3p	-2.771568)			
	4s	-1.608361	7.55389	-2	-1.608080
	5s	-1.019050	1.03475	-2	-1.018850
	6s	-0.703001	3.46128	-3	-0.702865
	7s	-0.514070	1.62531	-3	-0.513980
	8s	-0.392207	9.10839	-4	-0.392143
	9s	-0.309050	5.68709	-4	-0.309005
	10s	-0.249788	3.81929	-4	-0.249754
Ne VIII	(3p	-3.613926)			
	4s	-2.088871	5.40453	-2	-2.088805
	5s	-1.325042	7.53194	-3	-1.324935
	6s	-0.914792	2.53186	-3	-0.914710
	7s	-0.669305	1.19153	-3	-0.669245
	8s	-0.510849	6.68580	-4	-0.510805
	9s	-0.402664	4.17782	-4	-0.402632
	10s	-0.325532	2.80724	-4	-0.325508

TABLE IV. Comparison of Absorption Oscillator Strengths for Several Transitions
in Li-like Ions Li I to Ne VIII with Results of Other Works
See page 37 for Explanation of Tables

$$2s \rightarrow np$$

Ion	This work	min [18]	max [18]	[19]
		$2s \rightarrow 4p$		
Li I	0.004415	0.004939	0.004299	0.0045
Be II	0.030955	0.03189	0.03064	0.0306
B III	0.049598	0.05175	0.04891	0.0486
C IV	0.061414	0.06365	0.06032	0.0610
N V	0.068987	0.06877	0.06789	0.0696
O VI	0.074263	0.07404	0.07321	0.0766
F VII	0.078147	0.07788	0.07714	0.0814
Ne VIII	0.081199	0.08099	0.08028	0.0850
		$2s \rightarrow 7p$		
Li I	0.001042	0.001136	0.001030	0.0011
Be II	0.005001	0.005155	0.004957	0.0052
B III	0.007350	0.0076	0.0072	0.0078
C IV	0.008716	0.009028	0.008597	0.0092
N V	0.009544	0.009535	0.009428	0.0102
O VI	0.010098	0.01020	0.01004	0.0107
F VII	0.010494	0.01057	0.01050	0.0112
Ne VIII	0.010798	0.009191	0.009028	0.0114

$$2p \rightarrow 3d$$

Ion	This work	max [25]	min [25]	[19]	[26]	Exp.
Li I	0.64027	0.65369	0.63851	0.667	0.654	0.643 [27]
Be II	0.63391	0.63531	0.63190	0.652	0.642	—
B III	0.64070	0.63811	0.63132	0.651	0.645	—
C IV	0.64783	0.64601	0.64483	0.654	0.651	0.6483 [28]
N V	0.65372	0.65082	0.65070	0.658	0.656	—
O VI	0.65847	0.65593	0.65564	0.662	0.660	0.6321 [29]
F VII	0.66234	0.66009	0.65961	0.666	0.663	—
Ne VIII	0.66554	0.66325	0.66291	0.667	0.666	—

TABLE IV. Comparison of Absorption Oscillator Strengths for Several Transitions
in Li-like Ions Li I to Ne VIII with Results of Other Works
See page 37 for Explanation of Tables

$$2p \to nd$$

Ion	4d	5d	6d	7d	8d	9d	
Li I	0.12318	0.04640	0.02300	0.01323	0.008374	0.005659	This work
	0.12321	0.04632	0.02293	0.01333	0.008579	0.005918	max [25]
	0.12294	0.04618	0.02283	0.01314	0.008354	0.005653	min [25]
Be II	0.12325	0.04660	0.02313	0.01332	0.008434	0.005657	This work
	0.12362	0.04663	0.02316	0.01334	0.008460	0.005772	max [25]
	0.12269	0.04629	0.02294	0.01321	0.008364	0.005703	min [25]
B III	0.12337	0.04647	0.02303	0.01325	0.008382	0.005664	This work
	0.12282	0.04615	0.02286	0.01315	0.008318	0.006426	max [25]
	0.12264	0.04612	0.02282	0.01312	0.008298	0.005634	min [25]
C IV	0.12338	0.04629	0.02289	0.01316	0.008318	0.005617	This work
	0.12278	0.04593	0.02270	0.01304	0.008234	0.005557	max [25]
	0.12244	0.04587	0.02266	0.01302	0.008231	0.005504	min [25]
N V	0.12332	0.04611	0.02276	0.01307	0.008258	0.005575	This work
	0.12283	0.04583	0.02259	0.01297	0.008217	0.005531	max [25]
	0.12253	0.04572	0.02253	0.01293	0.008160	0.005515	min [25]
O VI	0.12324	0.04595	0.02265	0.01300	0.008209	0.005540	This work
	0.12257	0.04586	0.02248	0.01297	0.008144	0.005489	max [25]
	0.12248	0.04558	0.02245	0.01288	0.008131	0.005439	min [25]
F VII	0.12316	0.04582	0.02256	0.01294	0.008166	0.005510	This work
	0.12269	0.04550	0.02239	0.01283	0.008099	0.005479	max [25]
	0.12242	0.04544	0.02236	0.01271	0.008039	0.005460	min [25]
Ne VIII	0.12308	0.04570	0.02248	0.01288	0.008131	0.005484	This work
	0.12250	0.04538	0.02232	0.01279	0.008067	0.005442	max [25]
	0.12238	0.04532	0.02229	0.01263	0.008058	0.005430	min [25]

TABLE V. Comparison of Some Quantum Defects for Li I and C IV
Obtained by Different Computations with Experimental Results
See page 37 for Explanation of Tables

ion	state	$\mu_l^{\mathbf{comp}}$	$\mu_l^{\mathbf{exp}}$	$\delta\mu_l$	$\delta\mu_l(\text{EP})$ [16]	$\delta\mu_l(\text{CC})$ [16]
Li I	3s	0.40280	0.40392	-0.00112	+0.00063	-0.00226
	4s	0.40124	0.40178	-0.00054	+0.00103	-0.00225
	5s	0.40059	0.40089	-0.00030	+0.00120	-0.00225
	6s	0.40025	0.40043	-0.00018	+0.00129	-0.00225
	3p	0.04452	0.04445	+0.00007	+0.00008	-0.00174
	4p	0.04619	0.04567	+0.00052	+0.00020	-0.00182
	5p	0.04693	0.04622	+0.00071	+0.00026	-0.00186
	6p	0.04733	0.04652	+0.00081	+0.00028	-0.00190
	3d	0.00052	0.00147	-0.00095	+0.00014	-0.00051
	4d	0.00073	0.00167	-0.00094	+0.00019	-0.00043
	5d	0.00083	0.00177	-0.00094	+0.00022	-0.00039
	6d	0.00089	0.00182	-0.00093	+0.00023	-0.00038
C IV	3s	0.15679	0.15770	-0.00091	+0.00056	-0.00102
	4s	0.15572	0.15615	-0.00043	+0.00097	-0.00102
	5s	0.15525	0.15547	-0.00022	+0.00116	-0.00102
	6s	0.15500	0.15512	-0.00012	+0.00124	-0.00102
	3p	0.03791	0.03792	-0.00001	+0.00041	-0.00118
	4p	0.03862	0.03818	+0.00044	+0.00081	-0.00118
	5p	0.03889	0.03828	+0.00061	+0.00100	-0.00114
	6p	0.03902	0.03835	+0.00067	+0.00108	-0.00114
	3d	0.00146	0.00162	-0.00016	+0.00019	-0.00020
	4d	0.00195	0.00194	+0.00001	+0.00028	-0.00021
	5d	0.00218	0.00210	+0.00008	+0.00030	-0.00022
	6d	0.00230	0.00222	+0.00008	+0.00029	-0.00024

TABLE VI. Comparison of Transition Energies, Absorption Oscillator Strengths,
and Effective Quantum Numbers for $3s \rightarrow np$ ($n = 3$–7) Transitions
in Na with Experiment and Other Calculations
See page 37 for Explanation of Tables

	$3p$	$4p$	$5p$	$6p$	$7p$	
$E_{3s,np}$	0.0773	0.1378	0.1596	0.1699	0.1756	This work
	0.0773	0.1379	0.1597	0.1699	0.1756	Exp. [20]
	0.0714	0.1316	0.1558	0.1641	0.1694	[21]
	0.0774	0.1387	0.1606	0.1709	–	[22]
n_{eff}	2.1174	3.1304	4.1349	5.1369	6.1380	This work
	2.1167	3.1326	4.1378	5.1403	6.1417	Exp. [20]
	2.1265	3.1506	4.3710	5.2940	6.2970	[21]
$f_{3s,np}$	0.9727	0.0142	0.0022	0.00066	0.00029	This work
	0.9688	0.0121	0.0020	0.0004	0.0001	[21]
	0.980	0.0133	0.0020	0.0006	–	[22]
	0.9694	0.0138	0.0021	0.00065	0.00028	[23]
	0.965	0.0127	–	–	–	[24]