Comment on "Energy levels of singly ionized cesium (Cs II)"*

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Five predicted but formerly unlocated energy levels in the $5p^5 5d$ configuration of Cs II are reported. Transitions involving these new levels and previously known levels allow the classifications of 19 lines in the spectrum of Cs II which have been observed but not classified prior to this time.

In 1976, Reader[1] clarified the energy-level structure of Cs II and calculated energy levels for the $5p^5(5d+6s)$, $6p$, and $(6d+7s)$ configurations. This comment reports the location of five energy levels calculated by Reader.[1] These five new levels, together with the three levels found by Reader,[1] one found by Reader and Epstein,[2] and the levels reported by Wheatley and Sawyer[3] and reinterpreted by Reader,[1] complete the configurations mentioned above. The classification of 19 observed[4-7] but previously unclassified[4] lines in the spectrum of Cs II follows from transitions involving the five new levels.

Table I displays the new energy levels in Cs II. The first column gives the designation of each level in terms of the $J_1 l$ basis set. These assignments are based on the dominant composition amplitude of the corresponding states as given by Reader.[1] Columns two and three give the observed and calculated[1] energies of the new levels. The observed energy levels were located by combining wave numbers of observed lines[4-7] with previously located levels.[1] Combinations were selected which gave tentative energy levels in the vicinity of the calculated values. For each energy level several of the tentative values agreed very closely on the location of the level. In this manner the five new levels were located. In each case only one value of close agreement arose so there was no ambiguity in choosing the correct energies. The observed energies in Table I are weighted averages of the energies predicted by the individual transitions involving each level. The statistical weights used in determining each average value and its uncertainty are based on the number of significant figures in the published wavelengths.[4-7] Each uncertainty is the rms-weighted deviation from the weighted average.

Table II gives the classifications of 19 lines in Cs II which locate the new levels. Formerly the lines had been observed[4-7] but not classified.[4] The designations of the $5p^5 6p$ and $7p$ configurations are directly from Reader.[1]

Although it is possible that some or all of the new levels reported here are only the results of spurious coincidences, this seems highly unlikely. The close agreement between the observed and calculated values in Table I, the small uncertain-

TABLE I. New energy levels in Cs II.

Designation (nominal)	Observed level value (cm^{-1})	Calculated level value [a] (cm^{-1})
$5d\,\frac{1}{2}\,[1\,\frac{1}{2}]^0_2$	128 319.69 ± 0.10	128 291
$5d\,\frac{1}{2}\,[2\,\frac{1}{2}]^0_2$	126 697.17 ± 0.55	126 604
$5d\,\frac{1}{2}\,[2\,\frac{1}{2}]^0_3$	129 420.02 ± 0.05	129 390
$5d1\,\frac{1}{2}\,[2\,\frac{1}{2}]^0_2$	115 675.37 ± 0.33	115 688
$5d1\,\frac{1}{2}\,[2\,\frac{1}{2}]^0_3$	118 269.21 ± 0.29	118 281

[a]Reference 1.

TABLE II. New classifications in Cs II.

Wavelength (Å)	Vacuum wave number (cm^{-1})	Implied initial level (cm^{-1})	Classification
6646.564	15 041.22	128 319.81	$5d\,\frac{1}{2}[1\frac{1}{2}]^0_2 - 6p\,\frac{1}{2}[\frac{1}{2}]_1$
6627.77 [a]	15 083.9	128 319.2	$-6p\,\frac{1}{2}[1\frac{1}{2}]_2$
3614.989	27 654.74	128 319.62	$-7p1\frac{1}{2}[\frac{1}{2}]_1$
6724.476	14 866.95	126 697.55	$5d\,\frac{1}{2}[2\frac{1}{2}]^0_2 - 6p\,\frac{1}{2}[1\frac{1}{2}]_1$
5984.393	16 705.52	126 697.58	$-6p\,\frac{1}{2}[1\frac{1}{2}]_2$
3397.187	29 427.70	126 696.39	$-7p1\frac{1}{2}[2\frac{1}{2}]_2$
3324.5	30 071	126 695	$-7p1\frac{1}{2}[1\frac{1}{2}]_2$
7149.554 [a]	13 983.04	129 420.06	$5d\,\frac{1}{2}[2\frac{1}{2}]^0_3 - 6p\,\frac{1}{2}[1\frac{1}{2}]_2$
3655.73 [b]	27 346.5	129 419.6	$-7p1\frac{1}{2}[1\frac{1}{2}]_2$
6979.681	14 323.35	115 675.27	$5d1\frac{1}{2}[2\frac{1}{2}]^0_2 - 6p1\frac{1}{2}[1\frac{1}{2}]_1$
3861.489	25 889.43	115 675.07	$-6p\,\frac{1}{2}[1\frac{1}{2}]_1$
3610.86 [a]	27 686.3	115 674.7	$-6p\,\frac{1}{2}[\frac{1}{2}]_1$
3605.535	27 727.25	115 675.85	$-6p\,\frac{1}{2}[1\frac{1}{2}]_2$
2480.7	40 299	115 675	$-7p1\frac{1}{2}[\frac{1}{2}]_1$
2415.0	41 395	115 676	$-7p1\frac{1}{2}[1\frac{1}{2}]_1$
3977.534 [a]	25 134.12	118 268.98	$5d1\frac{1}{2}[2\frac{1}{2}]^0_3 - 6p\,\frac{1}{2}[1\frac{1}{2}]_2$
2641.0	37 853	118 271	$-7p1\frac{1}{2}[2\frac{1}{2}]_2$
2613.6	38 250	118 272	$-7p1\frac{1}{2}[2\frac{1}{2}]_3$
2596.95	38 495.2	118 271	$-7p1\frac{1}{2}[1\frac{1}{2}]_2$

Wavelengths are from Reference 4, except [a]Reference 7 and [b]Reference 6.

ties in the observed values, and the absence of ambiguity in choosing the appropriate energy values all lend support to the identifications given here. Also, if the identifications are incorrect, then a number of lines expected to be strong in the Cs II spectrum have never been observed.

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[1]Joseph Reader, Phys. Rev. A 13, 507 (1976).

[2]Joseph Reader and Gabriel L. Epstein, J. Opt. Soc. Am. 65, 638 (1975).

[3]Marshall A. Wheatley and Ralph A. Sawyer, Phys. Rev. 61, 591 (1942).

[4]A. R. Striganov and N. S. Sventitskii, *Tables of Spectral Lines of Neutral and Ionized Atoms* (IFI/Plenum, New York, 1968), pp. 610–20.

[5]George R. Harrison, MIT *Wavelength Tables* (MIT, Cambridge, Mass., 1939).

[6]M. G. Balasse, J. Phys. Radium 8, 311 (1927).

[7]L. A. Sommer, Ann. Phys. (Leipzig) 75, 163 (1924).