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Preliminary List of Levels and *g*-Values for Ta II

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A new description of the spectrum emitted by singly ionized tantalum atoms has been compiled from observations made at this Bureau. The list of wavelengths contains about 2,500 lines between 5300 and 2000 A. About a third of these lines, including most of the strong ones, have been classified as transitions among energy levels that were identified with the help of well-resolved Zeeman patterns. The low and metastable levels arise from the electron-configurations $5d^2\,6s^2$, $5d^3\,6s$, and $5d^4$. The higher levels with which the low ones combine arise from the excited configurations $5d^2\,6s\,6p$ and $5d^3\,6p$. The presence of the $d^2\,s^2$ configurations in ionized tantalum, almost equal in stability with $d^3\,s$, is noteworthy because it is unknown in the homologous vanadium and columbium ions.

At various times during the past 25 years, the spectra of tantalum have been under investigation, at the National Bureau of Standards, not only to set up standard descriptions of them but also to analyze their structure. A description of the spectrum of the neutral tantalum atom and a preliminary list of levels for Ta I have already been published.[2,3] An analogous description of the spectrum emitted by singly ionized tantalum atoms has been completed and has, in part, been classified. The levels are communicated in the tables of this note. A revision and extension of the Ta I levels will follow in due course.

The spectrograms on which the descriptions of the spectra are based were obtained with the prism and grating spectrographs of this Bureau and cover the wavelength range from 2000 A, in the ultraviolet, to beyond 12,000 A in the infrared. The light sources were arcs and condensed sparks between electrodes of pure tantalum metal. They were operated in enclosures in which the air pressure was maintained at half an atmosphere or less so as to reduce the intensity of the background of continuous radiation that always accompanies tantalum arcs and sparks in air at normal pressure.

The clues to the term-structure of Ta I and Ta II were furnished by the Zeeman effect. So far as is known the first observations of the splitting of tantalum lines in magnetic fields were made especially for this investigation, in 1924, at the Brace Laboratory of Physics of the University of Nebraska, by the late Professor B. E. Moore. These earliest observations, measured and reduced at the National Bureau of Standards, exhibited some well-resolved, complex patterns for the stronger lines and gave the first insight into the structure of the tantalum spectra. Although McLenan and Durnford [4] published some Zeeman effects for tantalum lines, in 1928, their observations refer, apparently, only to unresolved patterns and were not used in this investigation.

Following Professor Moore's untimely death, further work on the Zeeman effect of tantalum was carried on at this Bureau. In 1932, a set of observations was made with the water-cooled Weiss magnet for which the light-source was a spark discharge between tantalum electrodes in air. In a second set of observations, made 11 years later, the light-source was a Ta arc operated in a Back Lamp [5] in which the air pressure was reduced to about ¼ atm. In the meantime, however, observations of tantalum were included in the Zeeman-effect program with the powerful magnet at the Massachusetts Institute of Tech-

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[2] C. C. Kiess and E. Z. Stowell, J. Research, NBS **12**, 459 (1934) RP671.
[3] C. C. Kiess and H. K. Kiess, J. Research, NBS **11**, 277 (1933) RP589.
[4] J. C. McLennan and A. M. I. A. W. Durnford, Proc. Roy. Soc. [A] **120**, 502 (1928).
[5] E. Back, Ann. Physik. (IV) **70**, 333 (1923).

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nology. These have been particularly valuable in resolving close patterns that were unresolved with the weaker fields.

The data acquired at both laboratories have led to the levels and g-values presented in the following tables. Table 1 contains the low and metastable even levels from the electron configurations $5d^2\,6s^2$, $5d^3\,6s$, and $5d^4$. Table 2 contains the odd levels from the configurations $5d^2\,6s\,6p$ and $5d^3\,6p$ resulting from excitation of an s or d electron out of the low configurations. The permissible transitions between these sets of levels give the classifications of more than a third of the known lines of Ta II, including most of the strongest ones.

Except for the levels of the lowest ^{5}F term the g-values do not agree strictly with those required for LS-coupling. However, the most plausible designation of the levels seems to be the term-symbols entered in the last column of table 1. Inspection of the table shows that intermingled with the components of ^{5}F and lying above them are triplet and probably singlet levels, apparently from the $d^2\,s^2$ configuration. It is rather striking that in singly ionized tantalum the configuration $d^2\,s^2$ is almost equal in stability to $d^3\,s$, whereas there is no evidence of its occurrence in singly ionized vanadium and columbium.

Details of the analysis of Ta I and Ta II will be presented in subsequent papers.

TABLE 1. *Even levels of* Ta II

Level	J	g	Designation	Level	J	g	Designation
0.00	1	0.000	$^5F_1$	13560.25	2	1.111	
1031.33	2	1.008	$^5F_2$	14494.90	2	1.472	$^5D_2$
2642.19	3	1.250	$^5F_3$	14581.00	3	1.004	
3180.04	2	0.750	$^3F_2$	14627.75	1	0.850	
4124.77	0	0/0	$^3P_0$	15726.06	3	1.476	$^5D_3$
4415.70	4	1.350	$^5F_4$	16424.36	2	1.405	
5330.66	1	1.550	$^3P_1$	17168.50	2	1.211	
5658.00	2	1.340	$^3P_2$	17231.22	4	1.23	$^5D_4$?
6186.72	5	1.33	$^5F_5$	17375.11	1	1.171	
6831.35	3	1.098	$^3F_3$	18500.60	2	1.462	
9690.46	2	1.063	$^1D_2$	22928.62	2	0.700	$^3F_2$
9746.33	4	1.225	$^3F_4$	23082.70	4	1.026	
10713.30	1	2.374	$^5P_1$	23294.72	3	1.120	
11767.14	3	0.915	$^3G_3$	23381.19	0	0/0	
11875.46	2	1.48	$^5P_2$?	23620.36	3	1.076	$^3F_3$
12435.85	3	1.614	$^5P_3$	24432.77	4	0.978	
12600.87	0	0/0	$^5D_0$	24869.61	3	0.995	
12705.32	4	1.021	$^3G_4$	25413.95	5	1.052	
12830.94	5	1.280	$^3G_5$	26829.09	3	0.855	
13475.40	1	1.510	$^5D_1$				

TABLE 2. *Odd levels of* Ta II

Level	J	g	Level	J	g
29256.87	2	0.522	46387.28	2	
33706.50	1	.291	46645.81	4	1.210
33715.15	2	.800	46831.39	3	1.204
36112.97	3		46850.69	2	1.097
36177.12	2	.947	47169.18	3	1.093
36763.73	3	1.169	47280.92	4	1.198
36987.73	1	0.685	47514.61	2	1.292
37230.80	2	.64	47596.02	1	
38515.55	2	1.026	47800.95	0	
38535.26	1	0.472	47825.41	3	1.198
38962.38	3	1.001	48064.50	0	
39295.83	3	1.140	48166.44	2	
39743.64	4	1.222	48223.11	2	1.448
40023.76	0		48470.35	4	1.268
40233.53	2	1.158	48666.55	2	1.137
40304.78	1	1.232	48776.36	1	0.750
41145.00	2	1.161	48962.66	3	1.275
41355.06	1	1.893	49080.44	2	1.33
41554.52	3	1.204	49536.28	3	1.318
41775.29	4	0.72	49592.90	2	1.63
42122.91	4	1.265	49646.60	3	1.045
42153.32	2	1.210	49887.03	1	2.023
42959.59	3	1.117	49937.82	4	
43064.95	2	1.061	51073.88	3	1.156
43544.44	3	1.086	51197.32	2	1.363
43553.87	1	1.50	51326.37	1	1.052
44005.16	4		51534.21	2	1.317
44206.19	1	0.255	52121.22	4	1.088
44259.20	2	1.251	52155.76	1	1.618
44430.38	3	0.950	52580.41	3	1.403
44434.70	0		52824.53	1	0.930
44585.33	5	1.245	53465.72	3	1.226
44626.00	4	1.264	53644.82	2	1.339
44835.23	3	1.34	54533.76	2	1.035
45233.85	1	1.461	54648.81	3	0.935
45446.91	2	1.150	55128.36	3	1.250
46174.63	1	1.361	56018.75	2	0.991
46286.97	4	1.405	56142.49	4	1.26

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