ANALYSIS OF THE SPECTRUM OF TREBLY IONISED ZINC : Zn IV.

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The spectrum of trebly ionised Zinc should be similar to that of trebly ionised Mercury and Cadmium. An analysis of the Hg IV spectrum was reported some time ago[1]; the present paper is concerned with an analysis of Zn IV. Cd IV has also been analysed and will be published shortly.

The wave-length data have been taken from R. O. Hutchinson.[2] These measurements are not accurate and the wave-lengths differ sometimes from those of Laporte and Lang[3] by more than 0·5 Å in the region common to the two. A similar error is even more serious in the case of Zn IV lines which are of shorter wave-length. Accordingly the common differences sometimes vary by as much as 40 cm.$^{-1}$ so that mere recurring differences are not to be relied on for purposes of classification. A consideration of the intensity and completeness of the multiplets is a surer indication of the correctness of the analysis. Another criterion is furnished by the question whether almost all the lines in the appropriate region are covered by the scheme. Thus the extreme ultraviolet spectra may be divided up into consecutive regions which belong almost exclusively to one stage in a series of successive stages of ionisation. A correct analysis embraces almost all the lines in one of these regions without leaving serious gaps. This is no doubt due to the fact that in any stage of ionisation only the low and middle levels are excited so that stray lines due to high levels not included in the classification and obtruding amongst the classified lines are quite rare. Though some apparently correct multiplets may be found by chance on account of the unreliability of the constant differences, all the important lines will not conform to the classification unless the intervals have been correctly chosen. Thus the region from λ 1768 to λ 1457 is almost wholly made up of Zn III lines and the correctness of the analysis is shown by the fact that the low and middle terms account for nearly all these lines. Similarly the spectrum of Hg IV was found to embrace nearly all the lines in the region λ 1658 to λ 1100 as combinations between low and

[1] *Proc. Ind. Acad. Sci.*, 1934, **1**, 39.

[2] *Astrophys. Jour.*, 1923, **58**, 280.

[3] *Phys. Rev.*, 1927, **30**, 328.

TABLE I.

		d^8s				d^7s^2			
		$^4F_{9/2}$	$^4F_{7/2}$	$^4F_{5/2}$	$^4F_{3/2}$	$^4F_{9/2}$	$^4F_{7/2}$	$^4F_{5/2}$	$^4F_{3/2}$
d^8p	$^4F^\circ_{9/2}$	(4) 81719 *3041* *5938*	(1) 75781 *3034*	..	..	(4) 79170 *3053* *5057*	(1) 74113 *3065*	..	..
	$^4F^\circ_{7/2}$	(1) 84760 *5945*	(3) 78815 *1817* *3298*	(0) 75517 *1835*	..	(1) 82223 *5045*	(3) 77178 *1805*	?	..
	$^4F^\circ_{5/2}$	..	(0) 80632 *3280*	(3) 77352 *1178* *2725*	(1) 74627 *1171*	..	(3) 78983 *2319*	(1) 76664 *1187* *1032*	(2) 75632 *1197*
	$^4F^\circ_{3/2}$	..	..	(1) 78530 *2732*	(2) 75798	..	..	(1) 77851 *1022*	(1) 76829
d^8p	$^4G^\circ_{11/2}$	(4) 79751 *3534*	..	..	..				
	$^4G^\circ_{9/2}$	(2) 83285 *4013* 5933	(3) 77352* *4015*	..	..				
	$^4G^\circ_{7/2}$	(2) 87298 *5931*	(3) 81367* *3667* *3291*	(1) 78076 *3643*	..				
	$^4G^\circ_{5/2}$	..	(3) 85034 *3315*	(4) 81719* *2736*	(3) 78983*				
d^8p	$^4D^\circ_{7/2}$	(1) 82447 *5942*	(2) 76505 *3463* *3299*	(1) 73206 *3458*	..				
	$^4D^\circ_{5/2}$	..	(1) 79968 *3304*	(1) 76664* *1412* *2754*	(1) 73910 *1431*				
	$^4D^\circ_{3/2}$	..	..	(1) 78076* *2735*	(0) 75341 *1323*				
	$^4D^\circ_{1/2}$	..	..	..	(1) 76664*				

* Blend.

middle terms. After a few trials an arrangement of multiplets was found in Zn IV which had this satisfactory property of including almost all the lines in the region from λ 1443 to λ 1030. The multiplets are given in Table I. Some combinations are represented by blends with others; this is due to insufficient resolution as can be easily seen by the fact that four pairs of close lines resolved by Laporte and Lang have been noted as single by Hutchinson. The terms deduced from these multiplets are given in Table II. By extend-

TABLE II. *Term Values in Zn IV.*

Configuration	Term	Value	Configuration	Term	Value
$3d^8 4s$	$^4F_{9/2}$	0	$3d^8 4p$	$^4G^\circ_{11/2}$	79751
	$^4F_{7/2}$	5938		$^4G^\circ_{9/2}$	83291
	$^4F_{5/2}$	9230		$^4G^\circ_{7/2}$	87299
	$^4F_{3/2}$	11962		$^4G^\circ_{5/2}$	90959
$3d^7 4s^2$	$^4F_{9/2}$	2539	$3d^8 4p$	$^4F^\circ_{9/2}$	81713
	$^4F_{7/2}$	7596		$^4F^\circ_{7/2}$	84757
	$^4F_{5/2}$	9915		$^4F^\circ_{5/2}$	86579
	$^4F_{3/2}$	10942		$^4F^\circ_{3/2}$	87759
$3d^8 4s$	$^2F_{7/2}$	11240	$3d^8 4p$	$^4D^\circ_{7/2}$	82443
	$^2F_{5/2}$	13840		$^4D^\circ_{5/2}$	85898
$3d^8 4s$	$^4P_{5/2}$	12550		$^4D^\circ_{3/2}$	87311
	$^4P_{3/2}$	16610		$^4D^\circ_{1/2}$	88603
	$^4P_{1/2}$	17630	$3d^8 4p$	$^2F^\circ_{7/2}$	94858
$3d^9$?	$^2D_{5/2}$?	−10512		$^2F^\circ_{5/2}$	99267

ing the classification to include the lines given by Bloch and Bloch[4] in the visible and near ultraviolet it is hoped shortly to improve the accuracy of these terms. Since no Rydberg sequences have been found and so no absolute term values are known, there is no point in drawing a $\sqrt{\frac{\nu}{R}}$ diagram. The course of the $d^8s\,^4F_{9/2} - d^8p\,^4F_{9/2}^\circ$ &c. lines and the various intervals in the iso-electronic-sequence Co I[5], Ni II[5], Cu III[6] and Zn IV are, however, given in Tables III and IV. Table V gives all the classified lines with their assignments.

[4] *Jour. de Physique*, 1934, **5**, 289.

[5] Goudsmit and Bacher, *Atomic Energy States*, McGraw Hill Co.

[6] B. V. Raghavendra Rao, *Zs. f. Phys.*, 1934, **88**, 135.

TABLE III.

Combination	Co I	Diff.	Ni II	Diff.	Cu III	Diff.	Zn IV
$d^8s^4F_{9/2}-d^8p^4F^\circ_{9/2}$ ..	29359	16804	46163	18384	64547	17166	81713
$d^8s^4F_{9/2}-d^8p^4G^\circ_{9/2}$ ..	28982	15989	44971	..	..	..	83291
$d^8s^4F_{7/2}-d^8p^4D^\circ_{7/2}$ ..	..	..	42228	..	..	..	76505

TABLE IV.

Term	Co I	$\Delta\nu$	Ni II	$\Delta\nu$	Cu III	$\Delta\nu$	Zn IV	$\Delta\nu$
$d^8s\ ^4F_{9/2}$	3482·76		8392·9		0		0	
$^4F_{7/2}$	4142·61	−659·85	9329·3	−936·4	1745	−1745	5938	−5938
$^4F_{5/2}$	4690·10	−547·49	10114·7	−785·4	3075	−1330	9230	−3292
$^4F_{3/2}$	5075·75	−385·65	10663·0	−584·3	3930	−855	11962	−2732
$d^8s\ ^2F_{7/2}$	7442·39		13549·1		7065		11240	
$^2F_{5/2}$	8460·77	−1018·38	14994·4	−1445·3	8810	−1745	13840	−2600
$d^8s\ ^4P_{5/2}$	13795·44		25034·6		..		12550	
$^4P_{3/2}$	14036·20	−240·76	24786·9		..		16610	−4060
$^4P_{1/2}$	14399·15	−362·95	24834·7		..		17630	−1020
$d^8p\ ^4G^\circ_{11/2}$	32430·56		53495·6		..		79751	
$^4G^\circ_{9/2}$	32464·66	−34·10	53364·0		..		83291	−3540
$^4G^\circ_{7/2}$	33173·30	−708·64	54261·5		..		87299	−4008
$^4G^\circ_{5/2}$	33674·32	−501·02	55017·6		..		90959	−3660
$d^8p\ ^4F^\circ_{9/2}$	32841·91		54556·1		64547		81713	
$^4F^\circ_{7/2}$	33466·78	−315·17	55416·7	−860·6	66027	−1480	84757	−3044
$^4F^\circ_{5/2}$	33945·81	−479·03	56074·0	−657·3	66785	−758	86579	−1822
$^4F^\circ_{3/2}$	34196·11	−250·30	56423·4	−349·4	67247	−462	87759	−1180
$d^8p\ ^4D^\circ_{7/2}$	..		51556·9		..		82443	
$^4D^\circ_{5/2}$	..		52737·4	−1180·5	..		85898	−3455
$^4D^\circ_{3/2}$	..		53633·9	−895·5	..		87311	−1413
$^4D^\circ_{1/2}$	..		54174·9	−541·0	..		88603	−1292
$d^8p\ ^2F^\circ_{7/2}$	35450·51		57079·1		66342		94858	
$^2F^\circ_{5/2}$	36329·79	−879·28	58491·8	−1412·7	68365	−2023	99267	−4409

TABLE V.

List of Classified Lines of Zn IV.

Int.	Wave-length	Wave-number	Classification
2	1443·0	69300	$d^8s\ {}^4P_{3/2}$—$d^8p\ {}^4D^\circ_{5/2}$
0	1434·8	69696	$d^8s\ {}^4P_{1/2}$—$d^8p\ {}^4D^\circ_{3/2}$
1	1430·7	69896	$d^8s\ {}^4P_{5/2}$—$d^8p\ {}^4D^\circ_{7/2}$
0	1414·4	70701	$d^8s\ {}^4P_{3/2}$—$d^8p\ {}^4D^\circ_{3/2}$
1	1409·1	70967	$d^8s\ {}^4P_{1/2}$—$d^8p\ {}^4D^\circ_{1/2}$
1	1388·8	72005	$d^8s\ {}^4P_{3/2}$—$d^8p\ {}^4D^\circ_{1/2}$
3	1387·8	72057	$d^8s\ {}^2F_{5/2}$—$d^8p\ {}^4D^\circ_{5/2}$ $d^8s\ {}^2F_{7/2}$—$d^8p\ {}^4G^\circ_{9/2}$
2	1374·8	72738	$d^8s\ {}^2F_{5/2}$—$d^8p\ {}^4F^\circ_{5/2}$
1	1366·0	73206	$d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4D^\circ_{7/2}$
1	1362·9	73373	$d^8s\ {}^4P_{5/2}$—$d^8p\ {}^4D^\circ_{5/2}$
2	1360·2	73519	$d^8s\ {}^2F_{7/2}$—$d^8p\ {}^4F^\circ_{7/2}$
1	1353·0	73910	$d^8s\ {}^2F_{5/2}$—$d^8p\ {}^4F^\circ_{3/2}$
1	1349·3	74113	$d^7s^2\ {}^4F_{7/2}$—$d^8p\ {}^4F^\circ_{9/2}$
1	1340·0	74627	$d^8s\ {}^4F_{3/2}$—$d^8p\ {}^4F^\circ_{5/2}$
0	1327·3	75341	$d^8s\ {}^4F_{3/2}$—$d^8p\ {}^4D^\circ_{3/2}$
0	1324·2	75517	$d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4F^\circ_{7/2}$
2	1322·2	75632	$d^7s^2\ {}^4F_{3/2}$—$d^8p\ {}^4F^\circ_{5/2}$
1	1319·6	75781	$d^8s\ {}^4F_{7/2}$—$d^8p\ {}^4F^\circ_{9/2}$
2	1319·3	75798	$d^8s\ {}^4F_{3/2}$—$d^8p\ {}^4F^\circ_{3/2}$
2	1307·1	76505	$d^8s\ {}^4F_{7/2}$—$d^8p\ {}^4D^\circ_{7/2}$
1	1304·4	76664	$d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4D^\circ_{5/2}$ $d^7s^2\ {}^4F_{5/2}$—$d^8p\ {}^4F^\circ_{5/2}$
1	1301·6	76829	$d^7s^2\ {}^4F_{3/2}$—$d^8p\ {}^4F^\circ_{3/2}$
3	1295·7	77178	$d^7s^2\ {}^4F_{7/2}$—$d^8p\ {}^4F^\circ_{7/2}$
3	1292·8	77352	$d^8s\ {}^4F_{7/2}$—$d^8p\ {}^4G^\circ_{9/2}$ $d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4F^\circ_{5/2}$
1	1284·5	77851	$d^7s^2\ {}^4F_{5/2}$—$d^8p\ {}^4F^\circ_{3/2}$
1	1280·8	78076	$d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4G^\circ_{7/2}$ $d^8s\ {}^4F_{5/2}$—$d^8p\ {}^4D^\circ_{3/2}$

TABLE V (*contd.*)

Int.	Wave-length	Wave-number	Classification
1	1273·4	78530	$d^8s\ {}^4F_{5/2}—d^8p\ {}^4F^\circ_{3/2}$
3	1268·8	78815	$d^8s\ {}^4F_{7/2}—d^8p\ {}^4F^\circ_{7/2}$
3	1266·1	78983	$\left\{\begin{matrix} d^8s\ {}^4F_{2/2}—d^8p\ {}^4G^\circ_{5/2} \\ d^7s^2\ {}^4F_{7/2}—d^8p\ {}^4F^\circ_{5/2} \end{matrix}\right\}$
4	1263·1	79170	$d^7s^2\ {}^4F_{9/2}—d^8p\ {}^4F^\circ_{9/2}$
4	1253·9	79751	$d^8s\ {}^4F_{9/2}—d^8p\ {}^4G^\circ_{11/2}$
1	1250·5	79968	$d^8s\ {}^4F_{7/2}—d^8p\ {}^4D^\circ_{5/2}$
0	1240·2	80632	$d^8s\ {}^4F_{7/2}—d^8p\ {}^4F^\circ_{5/2}$
0	1234·4	81011	$d^8s\ {}^2F_{5/2}—d^8p\ {}^2F^\circ_{7/2}$
3	1229·0	81367	$d^8s\ {}^4F_{7/2}—d^8p\ {}^4G^\circ_{7/2}$
4	1223·7	81719	$\left\{\begin{matrix} d^8s\ {}^4F_{9/2}—d^8p\ {}^4F^\circ_{9/2} \\ d^8s\ {}^4F_{5/2}—d^8p\ {}^4G^\circ_{5/2} \end{matrix}\right\}$
1	1216·2	82223	$d^7s^2\ {}^4F_{9/2}—d^8p\ {}^4F^\circ_{7/2}$
1	1212·9	82447	$d^8s\ {}^4F_{9/2}—d^8p\ {}^4D^\circ_{7/2}$
2	1200·7	83285	$d^8s\ {}^4F_{9/2}—d^8p\ {}^4G^\circ_{9/2}$
2	1195·8	83626	$d^8s\ {}^2F_{7/2}—d^8p\ {}^2F^\circ_{7/2}$
1	1179·8	84760	$d^8s\ {}^4F_{9/2}—d^8p\ {}^4F^\circ_{7/2}$
3	1176·0	85034	$d^8s\ {}^4F_{7/2}—d^8p\ {}^4G^\circ_{5/2}$
1	1170·6	85426	$d^8s\ {}^2F_{5/2}—d^8p\ {}^2F^\circ_{5/2}$
2	1145·5	87298	$d^8s\ {}^4F_{9/2}—d^8p\ {}^4G^\circ_{7/2}$
1	1136·0	88028	$d^8s\ {}^2F_{7/2}—d^8p\ {}^2F^\circ_{5/2}$
3	1049·8	95256	$d^9\ {}^2D_{5/2}—d^8p\ {}^4F^\circ_{7/2}$
2	1037·4	96395	$d^9\ {}^2D_{5/2}—d^8p\ {}^4D^\circ_{5/2}$
2	1029·9	97097	$d^9\ {}^2D_{5/2}—d^8p\ {}^4F^\circ_{5/2}$