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A NOTE ON THE SPECTRA OF DOUBLY AND TREBLY IONIZED LEAD

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ABSTRACT

In the spectrum of Pb III three new singlet terms *viz.* $6s7s\,^1S_0$, $6s7p\,^1P_1$ and $6s7d\,^1D_2$ have been found to give rise to seventeen new lines which are here reported.

Certain discrepancies between the classification of terms by A. S. Rao and A. L. Narayan and the writer are discussed.

In the spectrum of Pb IV the previously published classifications of lines by J. A. Carroll, A. S. Rao and A. L. Narayan are discussed, and certain anomalies are pointed out. Two schemes different in some respects from those already put forward are suggested.

SPECTRUM OF PB III

THE spectrum of Pb III has been discussed in several papers[1,2,3] published during the past two years. The investigation of this spectrum has been continued by the writer and has led to the identification of three more singlet terms, which have been classified as $6s7s\,^1S_0$, $6s7p\,^1P_1$ and $6s7d\,^1D_2$. In the meanwhile a further paper by A. S. Rao and A. L. Narayan[4] has appeared in which there is agreement with the writer with regard to the $6s7p\,^1P_1$ term but disagreement as to the identity of the term classified by the writer as $6s7s\,^1S_0$. As there are also further discrepancies between the results it was thought that it would be of interest to discuss these and to bring the information with regard to this spectrum up to date by adding a list of the new combinations which have been classified.

The data used in this investigation are the vacuum spark measurements of Mack,[5] of R. J. Lang (unpublished) and of the writer.[6] Spectrograms of the Schüler lamp discharge in the region from 1900A to 7000A obtained by the writer have also been found to be useful in this work. The writer is also

[1] K. R. Rao, A. L. Narayan and A. S. Rao. Indian Journ. Phys. **2,** 467 (1928).
[2] S. Smith, Proc. Nat. Acad. Sci. **14,** 878 (1928).
[3] S. Smith, Phys. Rev. **34,** 393 (1929).
[4] A. S. Rao and A. L. Narayan, Zeits. f. Physik **59,** 687 (1930).
[5] J. E. Mack, Phys. Rev. **34,** 17 (1929).
[6] S. Smith, Trans. Roy. Soc. Canada **22,** 331 (1928).

indebted to Dr. Lang for a plate of this spectrum taken on his vacuum spectrograph in the region 1300A to 2200A.

The two main points of disagreement between the classification of Rao and Narayan and that of the writer are in connection with the $6s7d\,^3D_{1,2,3}$ and $6s6d\,^1D_2$ terms. With regard to the $6s7d\,^3D_{1,2,3}$ terms Rao's choice does not lead to any observed lines in the predicted positions for the $6s6p\,^3P_{0,1,2}-6s7d\,^3D_{1,2,3}$ combinations, whereas the terms selected by the writer do give fairly close agreement between predicted and observed lines for these combinations. Moreover the observed lines λλ4094, 4128, which apparently arise from combinations between $6s7d\,^3D_{1,2}$ and the newly found term $6s7p\,^1P_1$, may be considered as further evidence in support of the validity of the writer's choice of the $6s7d\,^3D_{1,2,3}$ terms. Turning now to the term $\nu=104998$, classified by Rao as $6s6d\,^1D_2$ and by the writer as $6s7s\,^1S_0$, it will be noted that Rao gives λλ4272, 4496 as the combinations between this term and $6s7p\,^1P_1$ and $6s7p\,^3P_2$ respectively. If this classification is correct then the inner quantum number of the term in question clearly cannot be 0. However it is found that the wave-number difference between λλ4272, 4496 is 1163.6 whereas the value of $6s7p\,^3P_2-6s7p\,^1P_1$, deduced from the appropriate combinations using measurements in a region where the wave-lengths are known to a fairly high degree of accuracy, is 1158.4. This is so large a discrepancy that it throws doubt on the above mentioned classification of λλ4272, 4496. It is possible that λ4496 is a $6s6d\,^3D$ combination as this line differs in wave-number from the line λ4400, which also appears to be a line of doubly ionized lead, by 481.6. This is the value of the $6s6d\,^3D_{1,2}$ separation. The $6s6d\,^1D_2$ term has been previously given by the writer and λ3951 appears to be the combination between this term and the newly found $6s7p\,^1P_1$ term and not an *FG* combination as classified by Rao. The lines λλ2948, 3451, given by Rao as $6s7p\,^3P_{1,2}-6p7p\,^3P_2$ appear with considerable intensity on the Schüler lamp plates and are therefore to be attributed to Pb II.

The lines involving the new terms are given in Table I.

TABLE I. *New classified lines of Pb III.*

λI.A. air	Int.	ν	Classification	Term	Value
5780.0	3	17296	$6s7s^1S_0-6s7p^3P_1$		
*5191.9	3	19255	$6s6d^3D_2-6s7p^1P_1$		
*5064.4	1	19740	$6s6d^3D_1-6s7p^1P_1$		
4855.14	2	20591.0	$6p6p^3P_1-6s7p^3P_2$		
*4827.02	3	20710.9	$6s7p^1P_1-6s8s^3S_1$	Term	Value
4596.53	1	21749.5	$6s6p^3P_1-6s7p^1P_1$	$6s7s^1S_0$	104998
4499.51	6	22218.4	$6s7p^1P_1-6s7d^1D_2$	$6s7p^1P_1$	81600
4272.63	5	23398.2	$6s7s^1S_0-6s7p^1P_1$	$6s7d^1D_2$	59382
4128.21	2	24216.8	$6s7p^1P_1-6s7d^3D_1$		
4094.68	3	24415.1	$6s7p^1P_0-6s7d^3D_2$		
3951.94	7	25296.9	$6s6d^1D_2-6s7p^1P_1$		
*3689.32	5	27097.6	$6s7s^3S_1-6s7p^1P_1$		
3530.35	1	28317.7	$6s7p^3P_1-6s7d^1D_2$		
λI.A. vac.					
1711.23	4	58437	$6s6p^1P_1-6s7s^1S_0$		
1118.67	4	89392	$6s6p^3P_1-6s7s^1S_0$		
1070.83	0	93385	$6s6p^3P_0-6s7s^1S_0$ (?)		
961.01	1	104057	$6s6p^1P_1-6s7d^1D_2$		

* Given by Rao and Narayan.

Spectrum of Pb IV

The first investigation of this spectrum was made by Carroll,[7] who gave the $6s\,^2S_1-6p\,^2P_{1,2}$ doublet, two of the $6d\,^2D_{2,3}-5f\,^2F_{3,4}$ triplet, and two choices for the $6p\,^2P_{1,2}-6d\,^2D_{2,3}$ triplet, the first of which included the line λ1069, which has since been shown to be a Pb III line. An extension of this spectrum based on Carroll's identifications has recently been published by Rao and Narayan,[8] but their classification does not appear to be a very probable one. The lines λλ3909, 3279, 3089, selected in Rao's scheme have been found to belong to Pb III. λλ1726, 1796 chosen by Carroll and by Rao as two of the $6d\,^2D_{2,3}-5f\,^2F_{3,4}$ triplet are found as very strong lines on the Schüler lamp spectrogram and therefore, in all probability, are to be attributed to Pb II. The writer has attempted to make a more probable selection, and a tentative scheme based on Carroll's second choice for the diffuse triplet is presented in Table II.

Table II. *Class fied lines of Pb IV.*

λ I.A.	Int.	ν	$\Delta\nu$	Classification
*1028.61	15	97218		$6s\,^2S_1-6p\,^2P_2$
			21063	
*1313.12	15	76155		$6s\,^2S_1-6p\,^2P_1$
*922.53	4	108398		$6p\,^2P_1-6d\,^2D_2$
			21057	
*1116.10	5	89598		$6p\,^2P_2-6d\,^2D_3$
			2257	
*1144.94	5	87341		$6p\,^2P_2-6d\,^2D_2$
3002.78	2	33292.8		$6d\,^2D_2-7p\,^2P_2$
			2258.4	
3221.30	6	31034.4		$6d\,^2D_3-7p\,^2P_2$
			8063.0	
3962.45	6	25229.8		$6d\,^2D_2-7p\,^2P_1$
3052.66	7	32748.8		$7s\,^2S_1-7p\,^2P_2$
			8063.1	
4049.79	4	24685.7		$7s\,^2S_1-7p\,^2P_1$
2508.98	2	39844.8		$7p\,^2P_1-7d\,^2D_2$
			8063.5	
3087.10	4	32383.5		$7p\,^2P_2-7d\,^2D_3$
			602.2	
3145.60	2	31781.3		$7p\,^2P_2-7d\,^2D_2$

* Selected by Carroll.

An alternative classification of the triplets involving $6d\,^2D_{2,3}$ terms in which these terms are inverted, as in the case of the doublet D terms of Pb II,[9] is given in Table III. In these tables the wave-lengths are expressed in I.A.$_{air}$ above 2000A and in I.A.$_{vac}$ below 2000A. Mack's measures are used for the $6P-6D$ triplet in Table III.

[7] J. A. Carroll, Trans. Roy. Soc. **A225**, 357 (1925).
[8] A. S. Rao and A. L. Narayan, Zeits. f. Physik **61**, 149 (1930).
[9] H. Gieseler, Zeits. f. Physik **42**, 265 (1927).

TABLE III. *Alternative classification of lines of Pb IV.*

λI.A.	Int.	ν	$\Delta\nu$	Classification
*890.78	5	112261	21059	$6p\,^2P_1 - 6d\,^2D_2$
1096.47	2	91202	-1604	$6p\,^2P_2 - 6d\,^2D_2$
*1116.09	7	89598		$6p\,^2P_2 - 6d\,^2D_3$
2864.54	7	34899.4	-1606.6	$6d\,^2D_3 - 7p\,^2P_2$
3002.78	2	33292.8		$6d\,^2D_2 - 7p\,^2P_2$
3962.45	6	25229.8	8063.0	$6d\,^2D_2 - 7p\,^2P_1$

* Selected by Carroll in his first choice of the diffuse triplet.

The fundamental triplet has not been found in either scheme and the $7p\,^2P_{1,2}$ separation is larger than might be expected.

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