# Rodaíkanal Observatory.

# BULLETIN No. XCI.

# ON THE SPARK SPECTRA OF LEAD

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The spectrum of Lead has been the object of many investigations. Yet until recently little progress has been made in the identification of series relationships in the arc and spark spectra of the element. This element is the chemical analogue of C, Si, Ge and Sn; and since it has the same number and type of outer electrons its spectral structures may be expected, according to present-day theories, to resemble those of the abovementioned elements. Such resemblances between homologous spectra are often very close, though there are occasionally minor but significant differences, which may perhaps prove of importance in the refinement of modern atomic theories. Recently through the work of Thorsen<sup>1</sup>, Grotrian<sup>2</sup>, Sur<sup>3</sup> and McLennan<sup>4</sup>, a distinct advance was made in the analysis of the arc spectrum of Lead. The first spark spectrum of the element was investigated by Geissler.<sup>5</sup>

The preliminary attempts at the classifications of the second and third spark spectra of Lead, from the existing lists of published wavelengths was seriously handicapped by the lack of descriptive data. Descriptions of arc and spark spectra of the element in limited wavelength intervals have been published by various observers. The most reliable ones up to the year 1911 are quoted by Kayser in Volume VI of the Handbuch der Spectroscopie. They are by Kayser and Runge<sup>6</sup> (arc spectrum 2085 to 6002-A.U.), by Thalen<sup>7</sup> (spark spectrum 4058 to 6656 A.U.), by Exner and Haschek<sup>8</sup> (arc spectrum 2237 to 6002 A.U., and spark spectrum 2170 to 4572 A.U.), and by Eder and Valenta<sup>9</sup> (arc spectrum 5609 to 7229 A.U., and spark spectrum 4272 to 6793 and 2088 to 2733 A.U.). Since the appearance of this work in 1912 the spectrum of this element has been reinvestigated by Klein<sup>10</sup>, with greater accuracy by using a 20 feet concave Grating Spectro graph. All the abovementioned measures were based on Rowland's system of standard wavelengths. In addition to these, contributions to the spectra of Lead have been made by Kimura and Nikumura<sup>11</sup>, who, by photographing the cathode spectrum grouped some of the important lines under successive stages. No attempts were made by these authors to measure the wavelengths accurately. Only after the present work was begun was the writer able to procure a paper published by S. Smith<sup>12</sup>, who photographed by means of a two-metre concave grating, the vacuum spark between electrodes of the metal, in the region 2400 A to 4800 A. It is found however that the hot spark does not give the highest members of spark lines, which I have been able to photograph with the highest excitation in the condensed spark. This is clearly seen from an examination of the writer's spectrograms (plates II and IV).

The measurements till now available are not sufficient for a complete analysis of the spark spectrum of Lead, since it is desirable to know the degrees of excitation at which the various lines appear and also to know the character of the spectrum lines, i.e., their sharpness, diffuseness, etc. The experiments of the writer were therefore aimed at photographing the whole region 2050 to 7000 A, with higher dispersion and

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under different degrees of excitation as a preliminary to the analysis of the higher spark spectra The results show that the procedure is justified many additional lines having been discovered in this work. The new observations of the spark spectrum together with the lines which have been classified in the spectra of Pb III and Pb IV are presented in this paper. In addition to the accurate measurement of wavelengths attempts have been made in this investigation to improve upon the earlier descriptions by making a careful selection of the lines characterising Pb I Pb III Pb III and Pb IV. This critical differ entiation of lines belonging to different stages is generally made by photographing the spectrum under varying degrees of discharge

To provide data likely to be useful in identifying the spectra of higher stages of ionisation a study was made of the spark spectrum of pure Lead in air in vacuo and in an atmosphere of hydrogen at varying pressures and also of the arc in vacuum between electrodes of the pure metal. The spark was produced by a  $\frac{1}{2}$  kilo watt 20000 volt transformer. The secondary contained a battery of large plate condensers of capa city 0.03 m f d (constructed for the purpose) in parallel with the spark gap in the experimental chamber To distinguish lines due to different stages of ionisation the spectrum was photographed under varying degrees of discharge which is done by including in the secondary circuit a variable self inductance and capacity

#### Description of apparatus

Sources of radiation — The apparatus used for the study of the spack spectrum is shown in diagram I It consists of a pyrex bulb capacity about one htre with side openings EI through which the electrodes pass To the ends of these small pieces of metal can be fixed A plane plat of quartz is attached to the end of the long projecting tube and serves as a window through which the spectrum of the spark is photo graphed. The two side tubulures (TT) are intended for filling the flask with hydrogen Pure hydrogen gas from a generator after passing through drying agents is passed through the flask for nearly 30 minites, thereby driving the last traces of air from the flask By connecting the flask then to an air pump the flask could be exhausted to any desired pressure and the spark spectrum photographed



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The spectrum of the vacuum arc of the metal was photographed, using a specially constructed arc lamp as the source of radiation. A diagrammatic sketch of the vacuum arc is given to Figure II. It consists of a double-walled cylindrical vessel fitted with a vacuum joint for one electrode and an aperture opposite for light to emerge. The second electrode passes through a similar joint in the base of the lamp and the clip for the specimen is arranged so that the arc is struck as close as possible to the window, without arcing to the wall taking place. The lid of the vacuum chamber is a bronze disc, which has been ground to make a tight joint which can be sealed with suitable vacuum wax or grease. Connection to the vacuum pump is made through the base of the lamp and nozzles are provided so that the cylindrical wall may be kept cool with circulating water. Each electrode consists of a brass tube passing through a gland and having an insulated wire passing through it. Electrical connection is made to the terminal situated on the ebonite handle, provided for the manipulation of the arc. The glands have been filled with vacuum grease for maintaining a vacuum. The lamp operates steadily with currents varying from 4 to 6 amps.



Spectrographs employed.—The spectrograms were obtained in the first and second order of a 4-inch concave grating, of 10 feet radius of curvature in eagle mounting. These were supplemented by several plates taken with a Hilger  $E_2$  Quartz spectrograph, which is used not only to record the faint lines in the ultra-violet, but also for wavelength measurements in the region 2550 to 2050-A. In this region this spectrograph compares favourably in dispersion and resolving power with the concave grating spectrograph and at the same time, has a good light gathering power. Comparison spectra of the iron are are impressed on the plates after each of the exposures. The spectrographs. The region 3600 to 6500-A was also visually examined, with a view to study the behaviour of the lines under different conditions of excitation, by a constant deviation spectrograph. For photographing the region below 2500-A, the plates were sensitized in the manner described in Volume II of Baly's Spectroscopy, with comptometer oil. The exposure times ranged, in the case of the concave grating spectrograph from 10 to 30 minutes, while in the case of the quartz spectrograph, up to 2500-A, the times ranged from 5 to 10 minutes and in the region 2500 to 2050-A exposures of 15 to 30 minutes were given.

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Method of wavelength determination —All plates were measured in two directions with a Hilger comparator and the wave length measurements were made relative to International Secondary Standards in the spectrum of the iron arc. For the region below 3370 A the iron arc. wavelengths published by Burus were used. In the case of the prism spectrograms the wavelengths were calculated by means of Hartman's dispersion formula  $\lambda = \lambda_0 + ---$  where  $\lambda_0$  c and n are constants determined from the comparison spectrum and n the distance of the unknown line from a fixed point of reference on the plate. Spectrograms obtained with the grating are measured by using a linear scale

Intensity estimates were made directly from the plates as viewed in the measuring microscope on a scale of 0 to 10 The vacuum wave numbers corresponding to the observed wavelengths are taken from Kayser s Tabelle der Schwingungszahlen and are given in column 3 of Table I In column 1 are given the observed wavelengths in I A In column 2 are given the intensity estimates in column 4 the stages of ionisation of the prominent lines and in column 5 are given the lines classified in this investigation. The symbols accompanying the intensity values have the following meanings -

s = sharp d = diffuse bd = broad and diffuse and dd = very diffuse

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1115 0289686III1 *P -1 S2174 610 dd45970 81116 2489590IV1 *P -1 D2178 721s45884 11118 6389997III1 P -1 D2189 76645652 8I1123 45389012IV1 P -1 P2203 628dd45365 7II1145 0887336IV1 P -1 P2203 628dd45365 7II1145 0887336IV1 P -1 P2218 21345067 3I1165 1485830III1 P -1 P2218 21345067 3I1165 1485690III1 P -1 P2223 7488b44679 2I1167 0485690III1 P -1 P2224 67544675 81233 6881068IV 6 D_8-7p D2224 133dd44349 2I1250 6479962III1 P_8-1 D2259 760dd44298 81250 6479962III1 P_8-1 *D2264 731s44141 71259 5378167IV6 D -6p F2280 511s43886 31359 2276441IV 6s* D -6p^* D2287 521bd43651 41459 5372897III1 P_8-1 P2299 100d43651 41459 5271093III 1 P_8-1 P2294 16043657 51459 5372897III 1 P_8-	1104 8	0 <b>d</b>	90510	IV 6 D <sub>3</sub> —6p F	2	169 86	10bd	46071 4			
1116 2489590IV1 *P -1 D2178 721s45884 11118 6389397III 1 P -1 D2189 76645652 8I1123 45389012IV1 P_2-2 82192 43245597 21142 9187497III 1 P -1 P2203 628dd46365 7II1145 0887336IV1 P -1 P2203 628dd46365 7II1165 1485830III 1 P -1 F2237 488b44679 2I1165 1485630III 1 P -1 F2242 67544675 81165 1485630III 1 P -1 F2242 67544575 81233 6381068IV 6D_8-7p D2254 133dd44349 2I1239 6381068IV 70 D_8-7p D2254 731s44141 71239 5378167IV 6D -6p F2280 511s43886 31239 5378167IV 6 B <sup>1</sup> D -6p <sup>1</sup> D2287 521bd43702 01239 537867IV 1 *8 -2 P2290 170dd43651 41239 5372897III 1 P_7-1 P2294 1643597 1136 5271093III 1 P_7-1 P2296 65243528 2146 5271093III 1 P_7-1 S2296 65243588 2146 5372897III 1 P_7-1 S2296 65243589 2146 5271	11150	2	89686	III 1 <sup>3</sup> P - 1 S	2	174 61	550	45970 8			
1118 6389397III1P1D2189 76645652 8I1123 45389012IV1 $P_2-2$ 82192 43245597 21142 9187497III1P1P203 628dd45365 7III1145 6387336IV1P1P1P2203 628dd45365 7III1165 1485830III1P1P1P1P1165 1485830III1P1P1P11165 1485830III1P1P111165 1486690III1P1P111165 1486690III1P1P121167 0486690III1P1P111260 6470962III1P1D2254 133dd44349 2I1250 6178933III1P1D2264 73144141 71250 7178933III1P1D2280 511143886 31250 7276441IV6* DD6P2290 17043651 41250 7976150IV1*S -2 P2290 17<	1116 2	4	89590	IV 1*P-1 D	2	178 72	18	45884 1			
1123 45389012IV1 $P_2-2$ S2192 43245097 21142 9187497III1 $P-1$ $P$ 2203 628dd45365 7II1145 0387336IV1 $P-1$ $P$ 2203 628dd45365 7II1145 1485830III1 $P-1$ $P$ 2218 21345067 3I1167 0486690III1 $P-1$ $P$ 2237 488b44679 2I1167 0486690III1 $P-1$ $P$ 2242 67544575 81233 6381068IV6 $D_8-7p$ $D$ 2254 133dd44349 2I1256 6178933III1 $P_8-1$ $D$ 2259 760dd44238 81256 7178933III1 $P_8-1$ $D$ 2264 731s44141 71257 6378167IV6 $D-6p$ $P$ 2280 511s43886 31265 9276150'IV $1^8S - 2$ $P$ 2290 170dd43651 41265 9976150'IV $1^8S - 2$ $P$ 2290 170dd43651 41265 9976150'IV $1^8S - 2$ $P$ 2290 170dd43651 41265 9271093III $1P_8-1P$ 2294 16048575 51265 9'271093III $1P_$	11186	3	89397	III 1 P - 1 D	2	189 76	6	45652 8	т		
$i142 \cdot 9$ 1 $87497$ III $1 P - 1 \overline{P}$ $2203 62$ $8dd$ $45365 7$ II $1145 \theta$ 8 $87336$ IV $1 P - 1 \overline{P}$ $2218 21$ 3 $45067 3$ I $1165 1$ 4 $85830$ III $1 P - 1 \overline{P}$ $2237 48$ $8b$ $44679 2$ I $1165 1$ 4 $85690$ III $1 P - 1 \overline{P}$ $2237 48$ $8b$ $44679 2$ I $1167 0$ 4 $85690$ III $1 P - 1 \overline{P}$ $2242 67$ $5$ $44575 8$ $1233 \cdot 6$ $8 1068$ IV $6 D_8 - 7p$ D $2254 13$ $3dd$ $44349 2$ I $1250^{\circ}6$ 4 $79962$ III $1 P_8 - 1 D$ $2259 76$ $0dd$ $44238 8$ $1250^{\circ}6$ 4 $79962$ III $1 P_8 - 1 ^{\circ} D$ $2264 73$ $1s$ $44141 7$ $1250^{\circ}6$ 4 $79962$ III $1 P_8 - 1 ^{\circ} D$ $2264 73$ $1s$ $44141 7$ $1250^{\circ}6$ 4 $79962$ III $1 P_8 - 1 ^{\circ} D$ $2264 73$ $1s$ $434141 7$ $1259^{\circ}5$ 3 $78167$ IV $6 D - 6p$ F $2280 51$ $1s$ $43886 3$ $1559^{\circ}9$ 9 $76150$ IV $1 ^{\circ} S - 2 P$ $2290 17$ $0dd$ $43651 4$ $1559^{\circ}9$ 9 $76150$ IV $1 ^{\circ} S - 2 P$ $2299 02$ $1bd$ $43597 1$ $1559^{\circ}9$ 2 $71093$ III $1 P_8 - 1 P$ $2294 16$ $0$ $48575 5$ $1559^{\circ}9$ 2 $71093$ </td <td>1123 45</td> <td>3</td> <td>89012</td> <td>IV 1 P<sub>2</sub>-2 S</td> <td>2</td> <td>192 43</td> <td>2</td> <td>45597 2</td> <td></td> <td></td> <td></td>	1123 45	3	89012	IV 1 P <sub>2</sub> -2 S	2	192 43	2	45597 2			
1145 0       9       87336       IV       1       P - 1       D       2218 21       3       4506 7       II         1165 1       4       85830       III       1       P - 1       P       2218 21       3       4506 7       I         1165 1       4       85830       III       1       P - 1       P       2237 48       8b       44679 2       I         1167 0       4       85690       III       1       P - 1       S       2242 67       5       44575 8         1233 6       8       81068       IV       6       D <sub>8</sub> -7p       D       2259 76       0dd       44393 3       I         1250 6       4       79962       III       1       P <sub>8</sub> -1 P       2264 73       1s       44141 7         1250 6       4       79962       III       1       P <sub>8</sub> -1 *D       2264 73       1s       44141 7         1250 75       3       78167       IV       6       D -6p       F       2280 51       1s       43886 3         1932 9 5       3       78167       IV       6 B <sup>3</sup> D -6p P       2287 52       1bd       43702 0         1932 9 7       9       76150	11429	1	87497	III 1 P – 1 P	2	203 62	658	45365 7	ΤT		
1165 1485830III1P<-1P2237488b4067921167 0486690III1P<-1	11450	8	87336	IV 1 P-1 D	2	218 21	3	45067 3	τ		
1167 0486690III1P1S2242 67544575 81233 63181215III1 *P1P1P1233 6881068IV6 $D_g$ 7pD2242 67544575 81233 6881068IV6 $D_g$ 7pD2242 67544575 81250 6479662III1 $P_g$ 7pD2259 760dd44393 3I1256 9178933III1 $P_g$ 1*D2259 760dd44238 81256 9178933III1 $P_g$ 1*D2264 731s44141 71274 6078456III1 *P_g1*D2276 583s43911 91379 5378167IV6D-6pF2280 511s43886 3138 9276441IV6* D-6p * D2287 521bd43702 0131 8372897III1 $P_g$ 1P2293 021bd43597 1131 8372897III1 $P_g$ 1P2296 65243528 21436 6271093III1*P - 182296 65243528 21V91436 6271093III1*g - 192300 354s43458 21V9-295	1165 1	4	85830	III 1 P -1 P	2	2237 48	8b	44679 2	Ť		
1231 3181215III1 *P1 $\overline{P}$ 2246 8310bd44493 3I1233 6881068IV6 $D_2 - 7p$ D2254 133dd4439 2I1250 6479662III1 $P_2 - 1$ D2259 760dd44238 81256 9178933III1 $P_2 - 1$ *D2259 760dd44238 81256 9178933III1 $P_2 - 1$ *D2264 731s44141 71274 6078456III1 *P_2 - 1 *D2276 583s43911 91379 5378167IV6 D -6p F2280 511s43886 3138 9276441IV6* D -6p F2280 511s43886 3138 9276441IV6* D -6p F2290 170dd43651 4138 9372897III1 $P_2 - 1$ P2293 021bd43597 1137 9372897III1 $P_2 - 1$ P2294 16048575 51436 6271093III1*P - 1 S2296 6524358 2IV9 D - 2951436 6271093III1*P - 1 S2296 6524358 2IV9 D - 2951436 5IV6* D_2 -6pD2300 354s43458 2IV9 D - 295	1167 0	4	85690	III $1 P - 1 S$	1 2	2242 67	5	44575 8	-		
12336881068IV6 $D_8 - 7p$ D2254 133dd44349 2I12506479962III1 $P_8 - 1$ D2259 760dd44238 812569178933III1 $P_8 - 1$ *D2259 760dd44238 812569178933III1 $P_8 - 1$ *D2264 731s44141 712746078456III1 $P_8 - 1$ *D2276 583s43911 913795378167IV6D-6pF2280 511s43886 314082276441IV6s <sup>1</sup> D-6p <sup>1</sup> D2287 521bd43702 014082976150IV1 $^{18}$ S-2P2290 170dd43651 41408372897III1 $P_8 - 1$ P2293 021bd43597 11408372897IIII1 $P_8 - 1$ P2296 65243528 214085IV6s <sup>1</sup> $D_8 - 6p$ D2300 354s43458 2IV9	<b>1231 3</b>	1	81215	Ш17Р ГР		2246 83	10hd	44493 3	т		
1250 6       4       79962       III 1 $P_8-1$ D       2259 76       0dd 44238 8         1256 9       1       78933       III 1 $P_8-1$ D       2259 76       0dd 44238 8         1274 6       0       78456       III 1 $P_8-1$ D       2264 73       1s       44141 7         1279 5       3       78167       IV 6 D -6p F       2280 51       1s       43886 3         1315 2       2       76441       IV 6s <sup>1</sup> D -6p <sup>1</sup> D       2287 52       1bd 43702 0         1315 2       9       76150       IV 1 ${}^{18}S -2$ P       2290 17       0dd 43651 4         1474 8       3       72897       III 1 $P_{2^{-1}} P$ 2293 02       1bd 43597 1         1474 8       3       72897       III 1 $P_{2^{-1}} P$ 2294 16       0       48575 5         1474 8       3       72897       III 1 $P_{2^{-1}} P$ 2296 65       2       48588 2       IV 9 D - 295         1474 8       3       72897       III 1 $P_{2^{-1}} P$ 2296 65       2       48588 2       IV 9 D - 295         1474 8       3       72897       III 1 $P_{2^{-1}} P$ 2296 65       2       48588 2       IV 9 D - 295         1475 9       1d       69585 <t< td=""><td>1233-6</td><td>8</td><td>81068</td><td><math>IV 6 D_8 - 7D D</math></td><td></td><td>2254 13</td><td>566</td><td>44949 2</td><td>î</td><td></td><td></td></t<>	1233-6	8	81068	$IV 6 D_8 - 7D D$		2254 13	566	44949 2	î		
1265 9       1       78933       III       1 $P_{g1}$ *D       2264 73       1s       44141 7         1279 5       3       78167       IV       6       D       -6p       F       2276 58       3s       43911 9         1379 5       3       78167       IV       6       D       -6p       F       2280 51       1s       43886 3         1438 2       2       76441       IV       6s <sup>1</sup> D       -6p <sup>1</sup> D       2287 52       1bd       43702 0         1375 2       9       76150       IV       1 *S -2 P       2290 17       0dd       43651 4         1418 3       3       72897       III       1 $P_{g-1} P$ 2293 02       1bd       43597 1         1418 3       3       72897       III       1 $P_{g-1} P$ 2294 16       0       48575 5         1438 5       2       7093       III       1 $P_{g-1} G$ 2396 65       2       48528 2       1V       9 D       285         1438 5       1       1d       69585       IV       68 <sup>1</sup> $D_{g-6} D$ 2300 35       48       48458 2       IV       9 D       285	1250.6	4	79962	III 1 $P_{s-1}$ D		2259 76	650 i	44938 8	•		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	1256-9	1	78933	III 1 P <sub>2</sub> -1 <sup>3</sup> D		2264 73	1 1 a	44141 7			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	1274-6	Ð	78456	III 1 <sup>3</sup> P <sub>8</sub> 1 <sup>8</sup> D		2276 58	39	49911 9			
1308 9       2       76441       IV $6e^{1}$ D $228752$ $1bd$ $437020$ 1308 9       9       76150       IV $1*S - 2P$ $228752$ $1bd$ $437020$ 1308 9       9       76150       IV $1*S - 2P$ $228752$ $1bd$ $437020$ 1308 9       9       76150       IV $1*S - 2P$ $229017$ $0dd$ $436514$ 1308 9       3       72897       III $1P_{27} - 1P$ $2293 \cdot 02$ $1bd$ $435971$ 1421 8       3       72897       III $1P_{27} - 1P$ $229416$ $0$ $485755$ 1430 95       2       71093       III $1^{3}P - 1S$ $2296655$ $2$ $435282$ 1430 95       IV $6s^{2}$ $D_{2} - 6p$ D $230035$ $4s$ $434582$ IV $2P$ $2sS$	1279-5	8	78167	IV 6 D 6p F		2280 51	1e	43886 3			
1313       2       9       76150       IV       1 *S       2       P       2290       150       45102       0         1313       2       9       76150       IV       1 *S       2       P       2290       150       45102       0         1313       3       72897       III       1 Pg-1 P       2293.02       1bd       43597       1         1321.8       3       72897       III       1 Pg-1 P       2294.16       0       43575.5       5         1336       5       71093       III       1 <sup>3</sup> P - 1 S       2296.65       2       43528.2       1V       9.2	1308.2	2	76441	$IV 6s^1 D - 6p^1 D$		2287 59	2 1bd	49709 0			
1011 S       3       72897       III $1 P_{2^{-1}} P$ 2293.02       1bd       43597 1         1011 S       3       72897       III $1 P_{2^{-1}} P$ 2293.02       1bd       43597 1         1011 S       3       72897       III $1 P_{2^{-1}} P$ 2294.16       0       48575.5         1010 F       2       71093       III $1^3 P_{-1} S$ 2296.65       2       43528.2         1017 F       1d       69585       IV $6s^3$ $D_2$ $0$ 2300.35 $4s$ 43458.2       IV $0$ $0$	1315 2	9	76150	IV 1*8-2 P	1 2	2290 17		43651 4			
1371 S       3       72897       III       1 $P_{2}$ —1 P       2294 16       0       48575 5         1336 6       2       71093       III       1 <sup>3</sup> P - 1 S       2296 65       2       43528 2         1437 1       1d       69585       IV       68 <sup>1</sup> $D_{2}$ —6p       D       2300 35       48       43458 2       IV       9 D       285		*x <sup>€</sup> 0⊧	73381	IV 6s <sup>1</sup> D <sub>2</sub> -7p <sup>1</sup> P	1	2293-07	2 164	49597 1			
1406 6         2         71093         III $1^{3}P - 1S$ 2296         65         2         43528         2           1407 1         1d         69585         IV $6s^{1}$ $D_{2}$ $6p$ D         2300 $35$ $48$ $43458.2$ $10^{-1}$ $20^{-1}$ </td <td>1971.8</td> <td>3</td> <td>72897</td> <td><math>III 1 P_{s-1}P</math></td> <td></td> <td>2294 16</td> <td>3 0</td> <td>48575 5</td> <td></td> <td></td> <td></td>	1971.8	3	72897	$III 1 P_{s-1}P$		2294 16	3 0	48575 5			
<b>1</b> 1d 69585 IV $68^{1}$ $D_{2}$ $-6p$ D 2300 35 48 43458 2 IV 2 D 289	1496 6	2	71093	III $1^{3}P - 1S$		2296 6	5 2	48598 9			
	期的1	1d	69585	IV 68 <sup>1</sup> D <sub>2</sub> -6p D		2300 8/	5 48	43458 2	٦V	2 P - 25	t.

### TABLE I

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TABLE I-cont.

$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Wavelength (I.A.)	Int.	Wave number in cm1	Stage and classification.	Wavelength (I.A.)	Int.	Wave number in cm1	Stage and classification.
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	2308 12	0 bd	43312.7		2868.19	3	34855.0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2312.70	0d	43226.2		2873.33	10	34792.6	I.
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	2317.45	2dd	43137.6		2937.55	4	340320	$IV 2^{2}P_{2} - 2^{2}D_{2}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$2332 \cdot 48$	8bd	42859.7	I.	2949.45	9dd	33894.7	TT
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	234372	1s	42654.1		2977.98	9	33570.0	I
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2353.91	0d	42469•5		3002.65	5s	33294.2	II.
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2360.19	1dd	42356.5		3010.19	3s	33210.8	
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	2368.54	2d	42207.2		3016.63	8dd	331330	TT
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2370.27	0s	42176.4		3025.55	2d	33042.3	~2.
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2382.28	38	41963.8		3028.77	<b>2</b>	33007.1	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2386 01	2s	41898.2		3031.68	4s	32975.5	דע
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2389.12	48	41843.6	<b>I</b> .	3043.90	10	32843.1	TTT 18D 18E
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2393 88	7dd	41760.5		3052.64	10	32749.0	TV
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2399.76	38	41658.1		3056.84	4	32704.0	$IV 1^2 D_{2} - ^2 P_{2}$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	2402.16	7bd	41649.3	Τ.	3062.42	4	32644.5	2, 1.02 12.
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2411.79	6bd	41450.4	I.	3071.54	4	32547.5	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	2416-18	0	41375.9		3087.13	5	32383.2	τν
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	9.418.78	Ő	41330.6		3089.17	7	32361.8	ITT 12D -13F
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	9494.91	0	41238.0		3103.00	4	32217.6	ITT
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	0498 70	8hd	41161.8	$V = 2^2 P_1 - 2^2 D_2$	3109.27	2	32152.6	2-2.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2420 FO	28	41078.1		3118.17	5	32060.8	т
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2400 00	u)hđ	40905.6		3129.62	4	31943.5	ÎTT
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2440 01	1004	40865.7	I.	3137.87	10	31859.5	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2440 00	10.0u	40585-2		3145.70	4	31780.3	TTT
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2403 21	0	40369.3		3176.59	10	31471.2	TTT 18D
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2470 00	2	40332.7		3191.49	1	31324.3	TTT 13D. 18F.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2478 02	0.4	40083.0		3214.82	õ	81097.0	111 1 D3-1 P2,
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2494 07	20 24	40058-3		3221.00	10	31037.3	$V 9^2 S - 9^2 D$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2495 61	ອດ	40088.4		3227.16	3	30978-1	IV 2 51-2 12.
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2497.16	28	20818-8		3231.31	3	30938-3	11.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2508 87	2 933	80559-8	TT.	3240.21	õ	30853.3	т
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2527 06	94J	10461-1	IV.	3242.95	9	30827.3	TTT 92D 93E
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2533.38	900 913	20428-8	τv	3247.70	2	30782.2	111 2 D <sub>3</sub> - 2 F <sub>3</sub> .
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2534.81	10	30014.7	ĨTĔ	3262.41	3	30643.4	T
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2562.37	10	98001-0	TV	3276.15	9	30514.9	TTT 93P93D
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2568.48	0	907084	îr	3279.30	9	<b>3</b> 0485.6	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2577.34	0 10	9994714	AL.	3280.09	9	30478.2	TV 18D
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2613.78	10	202414	r	3298.04	9	30313.3	$111 9^{3}P_{-}9^{3}D$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2614-28	9	90095-1	1. Y	3309.22	8d	30209.9	$111 - 2 D_1$ .
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2628.37	0	97000 I	а.	3360-40	48	29749.8	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2637.81	3	97999.C	тт	3361.59	<b>4</b> s	29739.3	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2638.53	5 0	27980.0	11.	3365.93	58	29701.0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2640.51	08	977100		3437.15	2s	29085.6	TIL
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2650.33	000	27602-1	т	3452.17	6d	28950.0	IL
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2957.15	48	97527.9	T	3455.18	8d	28933.8	III
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2663.23	10	97050-0	1.	3476.27	0	28758.3	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2697.60	50	90051-0		3483.46	9	28698.9	TTI 13F-13G.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2712.81	0	900012	ττ	3505 37	3d	28519.5	III 1 <sup>3</sup> F. 1 <sup>3</sup> G.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2717.38	6d	907549 907549	тт. Т	3530.39	3	28317.4	114 105.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2719.97	30	20704 A 20575-0	л., Т	3534.06	3d	28288.0	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2733.23	2	000709 905570	т. Т	3560.75	6	28076.0	TTT 11Da-14E
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2734.58	2	56997.9	1. T	3563-06	4	28057.8	$111 1^{3}F_{1} - 1^{3}G_{1}$
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2737.00	2	50525 0 90474-0	<b>.</b> .	3565.26	1	28040.5	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2740.87	2	004740		3567.16	3	28025.5	TIL 11D -8
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2745.51	4	00412 4 90904-5	$1V 2^{2}P_{2} - 3^{2}S_{2}$	3572 79	10s	27981.4	— — <i>"</i> " p.
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	2752.15	1	000Z40	LI 412 0 NI.	3586-29	5d	27876.0	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$2755 \cdot 81$	0	30270.3	т	2580.81	7d	27848 7	III 18F 18G
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	2802.00	10	500100	<u>т</u>	2502.95	68	27824.4	$IV 2^2D_{2} = y^2F_2$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$2823 \cdot 25$	10	004000	±.,	#R91-10	<b>1</b> s	27608.1	······································
2864:45 10 54500 0 11 212 213. 1 5055 00 200 200 200 200 200 200 200 200	2833.12	10	30280 4	$\mathbf{T} \nabla = 2^{2} \mathbf{P}_{0} - 2^{2} \mathbf{D}_{0}$	2620-66	10s	27467-3	Ι.
2	2864.45	10	84900.0	• T A • 2 - A 1 '3	1 0000 00	202		
		<b>2</b>						

Wavelength (IA)	Int	Wave numbei in cm <sup>1</sup>	Stag	se and classification	Wavelength (IA)	$\mathbf{Int}$	Wave number in cm <sup>-1</sup>	Btag	ge and classification
3648 61	1bd	27400 1			4534 54	3d	22046 8		
3655 56	8 <b>d</b>	27347 8	III	18F <sub>2</sub> -18G <sub>3</sub>	4571 45	7s	21868 8	III	$2^{3}P_{2}-2^{3}S_{1}$
3665 64	0	272726	III		4605 28	3sd	21708 1		
<b>3671 48</b>	10d	27229 3	I		4630 38	58	215858		
3674.75	4	272050	$\mathbf{III}$	1 <sup>8</sup> F <sub>4</sub> 1 <sup>3</sup> G <sub>8</sub>	4761 00	88	209981	III	1 <sup>3</sup> S <sub>1</sub> 2 <sup>3</sup> P <sub>1</sub> .
3683 57	10s	27139 9			4798 27	68	20835 6	III	1*812*P.
8689-22	8s	27098 2	III	$1^{8}S_{1} - 2^{1}P_{1}$	480218	<b>6</b> s	20818 1		
3699 52	0bd	27022 9			4827 15	0	207104	111	$2^{1}P_{1}-2^{3}S_{2}$
3706 22	3d	26974 0	ш	28P02 8S1	4855 20	1	20590 7		
<b>3714</b> 10	5dd	26916 8	II		4885 71	1	$20462\ 2$		
3719 30	2dd	26879 2			4941 12	18	20232 7		
8729 06	4	26808 8	ш	$2^{3}P_{1}-2^{3}S_{1}$	5003 59	38	19980 1	TIT	21P
3735 98	7	26759 2			0005.68	64	19971 8		1 ~
3740 13	108	26729 5			5043 21	10	19823 1	TΤ	
3749 22	1	266647			5062 91	39	19746 0	ÎTT	13D21P.
8786 20	8d	26404 2	11		5066 24	Sa	19789.0		
3827 66	<b>5</b> 8	26118 2	<b>III</b>	2 <sup>1</sup> P,-2 <sup>8</sup> D <sub>2</sub>	5117 31	2sd	19536 1		
3882 94	10s	26082 3	ш	$2^{3}P_{1}\alpha$	5139 42	28	19452.0		
8841 83	104	26021.9	ш	23Pg23Dg	5163 75	Да Бе	19360 4	τv	
3854 11	108	25989 0	III	138,-23Pe	5192.29	ha	19253 ()	ŤŤ	1°D21P.
3873 22	18	25811 0	IV		5201 65	69	19219 9		1.51 2.1
8909 29	5d	25572.9	ĪV	1ºD,-2º₽,	5907 17	6J	10100 0	ттт	18P9P.
3927 74	35	25452 8			5920717	00 974	10150 9	111	1-11-411
3948 79	188	25349 2			50-0 92	244	10099 0	TTT	180080
8952-11	84	25295 8	π	18P23P.	5974 51	5u 4e	19092 8	ŤΫ	1°F1-2°1'B
3962-58	88	25229 3		- 20 0	5372 65	10	18607 6	Ĩ	
3994 98	ls.	250241			5471.80	1	18270 5	ŤŤ	
4004 85	38	24965 8			5496 61	- 1s	11188 0		
4019 66	88	24870 8	Т		5523 50	58	18099 4	LIJ.	18D-2*P.
4081 48	84	24797 8	-		5544 60	1	18090 6	<u></u>	
4041 51	ĭ	24786 3			5545 11	10	18028 9	ΤT	
4049 88	- 7e	24685 1			5609 18	10	17828 0	ΤT	
4058 01	1044	24635 8	r		5664 49	38	17649 0		
4062 22	89	2461 8 2	Î		5677 53	8a	17608 4		
4077 61	0.1 0.4h	24517 9	-		5678.89	8.	17604.2		
4095 04	24	24412-9			5707 67	03 9e	175154		
4198 84	č2A	242160	TTT		577975	40	17297 0	ттт	1 <sup>1</sup> D <sub>2</sub> -2 <sup>3</sup> P <sub>2</sub>
4141 58	Rh	24138 7	ÎŢŢ	182	5898 19	284	171534		
4159 00	3dh	24068.5		1	5857 59	69	17067 1	TTT	1*D2*Pa
4168 05	79	23985-3	т		5876 65	78	17011 8	ÎT	
4174 BB	A.a.	28948.9	π	18n 18F	5890 33	60	16972.8		
4189 40	8	23903-0	τv	98828D	5893.01	Ra	16964 6		
4249 50	224	20500 V	ŤŤ	$2 D_1 - 2 I_1$	5030 01	0a 9a	16857-0		
4945 47	10	93547 4	TT .		5941.05	26 9a	16827 4		
4979 64	Ra Ra	200470	, <u>1</u> 1	11m91P	600913	<u>д</u> р Ка	16656 1		
1992 90	10	99752.0	1.1.1 TT	1.02-4.11	6002 10	08 Ka	16554 1		
4400-05 4400-05	10 182	221000	, 11 TT		6000 12	374 244	16497 9	ττ	
14A7 10	ୁ ଜୁନ	22110-0 9949688		•	6270 00	1 1	15860 7	**	
AAQR 10	γu Qa	9002Km	יי דדו	11739879.	6880 1K	Q.a	15010 F	TT	
<u>77</u> 0012 <u>7</u> 0079	0B 5}	22#00#2 99917#0	у Калария С С С С С С С С С С С С С С С С С С С	- 1°178	6700 04	2a 2a	14717 1	τ	
<del>71</del> 00 fU	*	444113	,		0134 74	90	72010 L		

TABLE I-cont

In addition to the spectrograms and wavelength measures obtained by the author, the wavelength of Carrol and Mack have been used for the region 2100 A

### Spectrum of Pb III

From the position of Pb in the table of elements it must be expected that the second spark spectrum consists of singlets and triplets and that the structure resembles generally that of the chemically and rolds atom or ion O III, Si III, Ge III, and Sn III, A1 II Ga II, In II and Tl II All these, except Pb III and Pb IV, have already been analysed. The present work on Pb III, Pb IV, therefore completes our knowledge of the series regularities in the spark spectra of elements of the fourth group. According to the theory of spectra developed by Pauli-Heisenberg, Russel and Hund, the characteristic terms arising out of any electronic configuration can be predicted with certainty and it will be seen that the results of the analysis of these spark spectra are in complete agreement with the theoretical predictions. The structure diagram of doubly ionised Lead may be written in the following manner :—



There are two electrons outside the complete spectroscopically neutral shells, which alone are effective in producing the optical spectrum. The most stable structure is that in which the two valency electrons are in the P<sub>1</sub> level. The spectroscopic term corresponding to this configuration is  ${}^{1}S_{0}$ . Other less stable configurations and their characteristic terms are obtained by keeping one of the electrons in the P<sub>1</sub> orbit and allowing the other to run through the orbits P<sub>2</sub>, Q<sub>1</sub>, O<sub>4</sub>, etc. The terms that these different electron configuration give rise to, may be predicted by the Hund Theory and are shown in the following table :---

	TABLE III.	
Electron configura- tion.	Torms predicted.	Terms observed.
$2 P_1$	$1^{1}S_{0}$	$1^{1}S$
1P <sub>1</sub> 1P <sub>2</sub>	1°P, 1'P	$1^{8}P, 1^{1}P$
$1P_1  1Q_1$	$1^{*}S_{1}, 2^{1}S_{0}$	$1^{8}$ S, $2^{1}$ S
$1P_1  1O_4$	a <sup>8</sup> F, a'F	
$1P_{1}$ $1P_{3}$	$1^{*}D, 1^{*}D$	$1^{8}D, 1^{1}D$
$IP_1 = 1Q_2$	2*P, 2'P	2°P, 2'P
$1P_1 = 1R_1$	$2^{*}S_{1}, 2^{1}S_{0}$	$2^{3}$ S, $2^{1}$ S
$1P_1  1O_4$	1 <sup>8</sup> F, 1 <sup>1</sup> F	1°F, 1'F
1P₁ 10₅	1°G, 11G	$1^{s}G$
$1P_{1}  1Q_{3}$	$2^{*}D, 2^{*}D$	$2^{*}D, 2^{1}D$
2 P <sub>2</sub>	$1^{*}\overline{P}$ , 1'D, 'S	18P

The first clue to the identification of the triplet systems in Pb. III was the detection of the fundamental group 1°D—1°F, which should occur in the visible and quartz regions and which could be examined under different experimental conditions. Observations have also been made in the visible region with a prism spectroscope to find the intense triplet  $1^{\circ}S_{1}-2^{\circ}P_{012}$ . The result is the identification of the prominent triplet given below :—

TABLE IV.						
λ	Int.	υ	∆u			
3854'05	12	<b>2</b> 59 <b>3</b> 9 <b>*</b> 4	1011			
4761.00	6	20998.1	163			
4798.27	4	20835.0				

2 -	A
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The choice of this is further supported by the detection of the member  $1^{*}D_{23}-2^{*}P_{2}$  in the calculated region and by the identification of the triplet  $2^{*}P-2^{3}S$  of the sharp secondary series The  $2^{*}P$  separation (4941) is found to be in complete agreement with the value predicted from the relativistic doublet law

The first principal, sharp and diffuse series fall in the extreme ultraviolet which does not lend itself to caleful examination of the lines Attempts were therefore made to fix by extrapolation and then to seek for confirmation by correlating the corresponding members of the spectra of corresponding elements A very valuable clue to the detection of these members is afforded by the application of the relativity laws to isoelectronic spectra of Hg-like atoms

An approximate idea of the 1<sup>a</sup>P<sub>18</sub> separation was obtained from the regular doublet sequence and from the relation that in the spectra of the same vertical group of the periodic table  $(\frac{\Delta^{\nu}}{Z^2})$  is approximately constant These give for 1<sup>a</sup>P<sub>18</sub> a value of about 14000 and for 2<sup>a</sup>P<sub>18</sub>, a value between 4000 and 5000

The following table shows the regular doublet sequence for  $1^{s} P_{19}$  and  $2^{s} P_{19}$  separations and the value of  $\left(\frac{\Delta \nu}{\sigma_{2}}\right)$  for elements of the same vertical group —

TABLE V — REGULAR DOUBLET SEQUENCE							
	$1^{3}P_{12}$ separation	≮∕∆⊍	$2^{3}P_{12}$ separation	¢∆ر			
Hg I	<b>4630</b> 6	8 25	1545 b	6 27			
Tl II	9339	983	2839	7 30			
Pb III	14595	10 9 <b>9</b>	(4941)	8 <b>4</b> 0			

TABLE VI — VARIATION OF $\Delta v/Z^{*}$						
At No Z	Element	23P12	∆u/Z³	1°P <sub>12</sub>	∆v/Z²	
6	C III	12 8	356			
14	Sı III	73 16	373	263	1 342	
32	Ge III	459	<b>44</b> 8	<b>1</b> 6 <b>42</b>	1 603	
50	n III	1222 8	491	<b>4</b> 031	1613	
82	Pb III	(4941)	60	14595	2171	

The application of the irregular doublet law to Hg like atoms indicated that the probable position of  $1^{*}P_{s}$ —1<sup>\*</sup>S<sub>1</sub> is at v 70000 nearly In applying this sequence the method of Millikan and Bowen is adopted as shown below In the usual notation, the irregular doublet law may be written as follows --

$$\frac{\nu^{1}}{R} = \frac{(n_{g}^{2} - n_{1}^{2}) z^{2} - z (n_{g}^{2}\sigma_{1} - n_{1}^{2}\sigma_{2}) + (n_{g}^{2}\sigma^{2} - n_{1}^{2}\sigma_{2}^{2})}{n_{1}^{2}n_{2}^{2}}$$

When a line results from transition between orbits of two different total quantum numbers,  $(n_s \& n_l)$  we get from the above equation, by transposition

$$\nu^{1} = \nu - \frac{R}{2} \frac{(Z-A)^{3} (n_{8}^{3} - n_{1}^{2})}{n_{1}^{2} n_{2}^{3}} = C^{1}Z + D^{1}$$

The expression on the left varies therefore linearly with the atomic number Z, for any given set of values  $n_s \& n_1$ . In the case of  $1^*P_s$ — $1^*S_1$  of Hg like atoms  $n_1 = 6$ ,  $n_s = 7$  and A = 79. The progressive variation of with atomic numbers is shown in the following table —

TABLE VII						
At No.Z	Element	v (1 <sup>3</sup> P2-v <sup>3</sup> S1)	$\nu^{1} = \nu - 8083 \ (Z A)^{2}$	Difference		
80	Hg. I	20782	19974	00004		
81	TI II	43501	40268	20294 22550		
82	Pb III	(71093)	63818	~~0000		

Aftempts have also been made, by the application of the Mosley law to the spectra of Ge III & Sn III and to the spectra of Hg-like atoms, to fix the approximate position of this triplet as a check on the irregular doublet sequence. A careful search was then made for the possible triplet  $1 {}^{s}P_{012}$ —1  ${}^{s}S_{1}$  among Caroll's  ${}^{18}$  measures, below 1450 A, having in view the relative order and magnitude of intensities and the probable ratio of intervals between the lines, with the result that the following triplet was fixed.

		TABLE VIII.		
λ	Int.	ν	Combinat	ion.
1406.6	2	71093	$1 \ {}^{8}P_{2} - 1 \ {}^{8}S_{1}$	14595
1167'0	4	85690	$1 P_{1} - 1 S_{1}$	3994
1115.0	2	89686	$1 P_0 - 1 S_1$	

Evidence for the possibility of this being the triplet in question is sought by searching for the complete six-line multiplet (diffuse) 1 \*P-1\*D.

The triplet 2  ${}^{s}P_{2}$ —2  ${}^{s}S_{1}$  being fixed in the case of Pb III, attempts have been made by the application of the irregular doublet sequence to locate the corresponding triplet in the case of Tl II, which has not been identified. In this case  $n_{2} = 8$ ,  $n_{1} = 7$  and A = 79. R  $(n_{2}^{2}-n_{1}^{2})$ 

	$\frac{\mathbf{R} (n_2^3 - n_1^2)}{n_1^2 n_2^2} = 584.61.$				
The sequence is—					
Z	Element.	ν.	$\nu^{1} = \nu - 524.6 \ (Z-A)^{2}$		
80	Hg. I	2753'6	2229.0		
81	Tl. II		[9690]		
82	Pb. III	21868.8	17146.9		

The interpolated value of  $v^{1}$  for Tl II is  $v^{1} = 9690 \ (\pm 500)$ .

 $\therefore \nu = 9690 + 2097 \ (\pm 500) = 11787 \ (\pm 500)$ , which is in the infra red, at about 8500-A.

A very interesting feature noticed in the spark spectrum of Lead is the partial inversion of the triplet F term,  $1 * F_{ss}$  being negative. The location and identification of the complete six-line multiplet  $1 * F_{m-1} * G$ , in approximately the calculated position is a strong evidence as to the correctness of the identification of the \*F terms.

The singlet system of lines is generally the most difficult to work out. When this analysis was first undertaken not much progress could be made at first in the identification of the singlet spectrum. The strong line 1048'9 (12) was suggested as 1 'S<sub>0</sub>—1 'P<sub>1</sub> and 1553'1 (20) as 1 'S<sub>0</sub>—1 <sup>8</sup>P<sub>1</sub>. While this work was in progress, the author's attention was drawn to a similar publication by Smith <sup>14</sup>. Although there is good agreement between the results of Smith and those of the author, there is disagreement in one or two important points. Smith has the following as 1 <sup>8</sup>P—1 <sup>8</sup>S and 1 <sup>8</sup>P—1 <sup>8</sup>P.

		TABLE IX.	
	1 <sup>8</sup> P <sub>2</sub> .	1 <sup>8</sup> P <sub>1</sub> .	1 <sup>3</sup> P <sub>0</sub> .
$^{8}S_{1}$	76447 (15)	91047 <b>(</b> 10)	95036 (7)
۶P°		78157 (15)	
$\mathbf{P}_{i}$	71095 (12)	85694 (15)	89687
$\widetilde{\mathbf{P}}_{2}$	85833 (15)	100428 (10)	

It was pointed out in a note communicated to Nature <sup>15</sup> that evidently Smith had the author's 1 <sup>8</sup>S<sub>1</sub> as his 1 <sup>8</sup>P<sub>1</sub> and that 1 <sup>8</sup>S<sub>1</sub> suggested by the writer was further supported by the location and identification of the second series 1 <sup>8</sup>S -2 <sup>8</sup>P, 1 <sup>8</sup>D -2 <sup>8</sup>P & 2 <sup>8</sup>P -2 <sup>8</sup>S. The 1 <sup>8</sup>P -1 <sup>8</sup>S suggested by the author followed the irregular doublet law for the isoelectronic spectra of Hg-like atoms more closely. The author therefore suggested that an interchange of the two levels 1 <sup>8</sup>S<sub>1</sub> & 1 <sup>9</sup>P<sub>1</sub> of Smith would bring the whole scheme into alignment. Attempts have also been made by the writer to identify the singlet spectrum, the results of which 3 have been published in a paper Smith<sup>14</sup> has since published another paper on the second spark spectrum of lead, in which the suggested modification was adopted There are still however two main points of disagreement between the classification of the writer and that of Smith The term  $\nu = 101434$ , classified by the author as 6s 6d <sup>1</sup>D<sub>9</sub> is classified by Smith as 6s 7s <sup>1</sup>S<sub>0</sub> Smith classified 1768 67 (5b540) as 1 <sup>1</sup>P<sub>1</sub>-1<sup>1</sup>D<sub>9</sub>, while the writer classified 17111 (58442) as this combination It will be seen from the irregular doublet sequence shown below (Table X), that both 1 <sup>1</sup>P<sub>1</sub>-1 <sup>1</sup>D<sub>9</sub> and 1 <sup>1</sup>D<sub>9</sub>-2 <sup>1</sup>P<sub>1</sub> identified by the writer show a distinctly better progression than those of Smith Further the line 1 <sup>1</sup>P<sub>1</sub>-1 <sup>1</sup>D<sub>9</sub> should be a strong line It is found that most of these strong lines of the triplet and singlet systems are found in the wavelength measures of McLennan, Young and Ireton, Bloch and Lang But the line 1768 67 identified by Smith as 1 <sup>1</sup>P-1 <sup>1</sup>D is not recorded by any of the previous investigators, while Carrol includes it as one of the lines belonging to Al These considerations indicate that the writer's classification and identification of 1 <sup>1</sup>D<sub>9</sub> is more probable

TABLE X --- IRREGULAR DOUBLET SEQUENCE

	1 <sup>1</sup> S <sub>0</sub> - 1 <sup>8</sup> P <sub>1</sub>	1 <sup>1</sup> S <sub>0</sub> -1 <sup>1</sup> P <sub>1</sub>	1 <sup>1</sup> P <sub>1</sub> -1 <sup>1</sup> D <sub>2</sub>
Hg I	39413	54065	17265
Tl II	52 <b>3</b> 90	75656	39501
Pb III	64387	95338	58442 - 56540

From the beginning of this investigation of the analysis of Pb III, it was felt that <sup>\*</sup>P <sup>\*</sup>P group should be strong as in the case of the chemically analogous atoms or ions 1 <sup>1</sup>D<sub>9</sub> and 2 <sup>1</sup>D<sub>9</sub> terms of Smith are probably 1 <sup>\*</sup>P<sub>1</sub> and 2 <sup>\*</sup>P<sub>1</sub> On this supposition <sup>\*</sup>P <sup>\*</sup>P group and the resulting combinations have been identified by the author, thus supporting the validity of the writer's identification of 1 <sup>1</sup>D<sub>9</sub> term The term values have been determined by assuming 1 <sup>\*</sup>F<sub>4</sub>=64 800, ( $\frac{\nu}{9} = 7200$ ) The resonance and ionisation potentials are 7 95 and 31 5 volts respectively, the largest term 1 <sup>1</sup>S<sub>0</sub>=255216 The details of the triplet and singlet systems identified in this investigation are given in the accompanying tables Table XV gives the configurations and term values for Ti II and Pb III and Table XVI gives other unclassified members of <sup>\*</sup>P<sub>19</sub> differences

		TABI	EXI				
· · · · · · · · · · · · · · · · · · ·	1*P <sub>2</sub> 176234	(14595)	1³P <sub>2</sub> 190829		<b>(899</b> 4)	1³P。 194823	
1°S, 105141	1406-6 71093	(2)	1167 0 85690	(4)		1115 0 89686	(2)
1*D <sub>1</sub>	1274 6 78456	(0)	1074 7 93049	(3)		1030 5 97040	(3)
1*D,	1266 9 78933	(1)	1069 2 93528	(4)			
1*Ds	1250 6 79962	(4)					
1°₽́₀ 109690	]		1231 3 81215	(1)			
1°P <sub>1</sub> 108332	1371 8 72897	(3)	1142 9 87497	(1)		(91491)	
1°P.	1165 1 85830	(4)	995 8 100422	(2)			

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۵	υ	J

TABLE XII.

	$2^{3}P_{3}$	4941	28P1	2 <sup>3</sup> P <sub>0</sub>
	79202		84143	84307
1 <sup>8</sup> S <sub>1</sub>	3854.11	A	4761.0	4798.27
105141	25939 (10s)		20998 (8s)	20835 (6s)
$2^{s}S_{1}$	4571.45		3729.06	3706.22
57334	21868 <sup>.</sup> 8 (7s)		26808'8 (4)	26974 (3)
$1^{s}D_{3}$	5857.59 (6)			
96272	17067 <sup>•</sup> 1 obs.			
	17070 cal.			
1°D2	5523.5 (5)			
97304	18099'4 obs.		Inf. red.	
	18102 <sup>°</sup> 0 cal.			
$1^{8}D_{1}$			Inf. red.	Inf. red.
97785				
$1^{s}\overline{P}_{s}$	Inf. red.		Inf. red.	
90407				
$1^{3}\overline{P}_{1}$	4141.56		5207.17	5252.33
103332	24139 (3)		19199 (6)	19034 (3)
1 <sup>8</sup> P <sub>0</sub>			(25570)	3952'1
109690				25296 (8)
2*D1	3939'77		3297.64	3279.91
53827	25375.0		30316(4)	304799 (2)
2*D2	3907.17		3276.19	
53628	25573.7 (5)		30514.5 (7)	
2*D3	3841.6			
53179	26023.3 (7)			

TABLE .	XIII.
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<u>19</u>	$\mathbf{I}_{3}\mathbf{F}_{4}$ (643)	$1^{3}F_{3}$ (-502)	1 <sup>3</sup> F <sub>2</sub>
	64800	65443	64941
1 <sup>8</sup> D <sub>8</sub>	$3176^{\circ}59$	3242 <sup>.</sup> 95	3191 <sup>•</sup> 49
96272	$31471^{\circ}2$ (10)	30827 <sup>.</sup> 3 (9)	31324 <sup>•</sup> 3 (1)
1°D <sub>2</sub>		3137 <sup>.</sup> 87	3089 <sup>.</sup> 17
97304		31859 (10)	32361 <sup>.</sup> 8 (7)
$\frac{1^{8}D_{1}}{97785}$			3043 <sup>.</sup> 9 32843 <sup>.</sup> 1 (10)
1 <sup>3</sup> G <sub>5</sub> 36280	3505 <sup>.</sup> 37 28519 <sup>.</sup> 5 (3)		
1 <sup>8</sup> G₄	3563'06	3483 <sup>-</sup> 46	
36742	28057'8 (4)	28698 <sup>-</sup> 9 (9)	
1³G₃	3674 <sup>.</sup> 75	3589 <sup>.</sup> 81	3655 <sup>.</sup> 56
37595	27205 (4)	27848 <sup>.</sup> 7 (7)	27347 <sup>.</sup> 8 (8)

	TABLE XIV	SINGLET SY	STEMS.	**
Classification.	λ	Int.	Observed.	Calculated.
1 <sup>1</sup> 81 <sup>8</sup> P.	1553.1	20	64387	•••
1'8,-1'P.	1048.9	12	95338	
$1^{1}P_{1} - 1^{8}S_{1}$	1826.2	0	54759	54737
1 <sup>1</sup> P,1 <sup>8</sup> D,	1597.8	0	62586	62577
$1^{1}P_{1}-1^{8}D_{1}$	1610'1	1	62107	62103
$1^{8}S_{1}-2^{1}P_{1}$	3689.22	7	27098.2	•••
$2^{1}P_{1} - 2^{3}S_{1}$	4827.1	1	20710'4	20709
$2^{2}P_{1}-2^{8}D_{2}$	3827'66	8	26118'2	
$1^{8}P_{1}-1^{1}D_{2}$	1118.6	3	89397	89393
$1^{1}P_{1} - 1^{1}D_{2}$	1711'1	4	58442	•••
$1^{1}D_{1}-2^{1}P_{1}$	4272'64	8	23398	23393
$1^{1}D_{2}-2^{8}P_{2}$	4496'12	3	22235	22234
$1^{1}D_{3}-2^{8}P_{1}$	5779'75	4	17297	17294
$1^{8}D_{1}-2^{1}P_{1}$	5192.29	4	19254	<b>1926</b> 0
$1^{8}D_{9}-2^{1}P_{1}$	5062.90	3	19746	19741
$1^{1}D_{3}-1^{1}F_{3}$	3560.75	6	28076	• • •
1 <sup>8</sup> D <sub>2</sub> -1'F <sub>8</sub>	4174.38	4	23949	• • •
2 <sup>8</sup> P <sub>1</sub> —α	3832.94	10	26082	• * *
<b>2</b> <sup>1</sup> P <sub>1</sub>	5003'59	3	19980	
1*D <b>,</b> β	4182.84	8	23903	
1'D,—	3567.16	3	<b>28026</b>	•••
The term $\circ$ above is	probably 2 <sup>1</sup> D <sub>2</sub> term,	while $\beta$ is of th	e nature of an F ter:	m and is probably a'F.

TABLE XIV .--- SINGLET SYSTEMS.

TABLE XVCONFI	URATIONS	AND TERM VALUES FOR	Tl. II & Pb. III.
Electron configuration.	Term.	Term values for Tl. II,	Term values for Pb. III.
2 P <sub>1</sub>	1'S.	164227	255216
1P <sub>1</sub> 1P <sub>9</sub>	,1°₽,	102499	176234
	<sup>8</sup> P1	111837	190829
	<sup>8</sup> Po	114784	194823
	$1^{1}P_{1}$	88565	159879
1P,1P,	$1^{s}D_{i}$	47403	96272
	*D,	47797	97304
	$^{\mathtt{P}}\mathrm{D}_{1}$	48082	97785
	'D,	<b>49064</b>	101434
1P <sub>1</sub> 1Q <sub>1</sub>	$1^{s}S_{1}$	59008	105141
$1P_{1}1R_{1}$	$2^{*}S_{1}$	•••	57334
1P <sub>1</sub> 1Q	2°P,	42199	79202
	${}^{*}\mathbf{P}_{1}$	<b>44</b> 650	84143
	³₽₀	44866	84307
	$2^{1}P_{1}$	38020	78043
1P11Q8	$2^{s}D_{s}$	26023	<b>53</b> 179
	$^{s}D_{s}$	26172	53628
	$^{n}D_{1}$	26300	53827
	2'D,	27333	58063
1P <sub>1</sub> 1P <sub>4</sub>	1*F.	(28000)	(64800)
	<b>'F</b> 8	28114	65443
	*F,	28014	64941
17.45	1'Fs	, <b>***</b>	73358
Thus the	1'G,	•••	36280
	°G,		36742
	"G <sub>8</sub>	***	37595

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TAE	BLE XVI	-OTHER	UNCLASSIFIED M	Em	BERS	OF	Pb.	III.	
	$1^{3}\mathbf{P}_{2}$		$1^{3}P_{2}$	ı				$1^{8}P_{0}$	
1.	1165.1	(10)	995	8	(2)			•	
	76447		91047						
2.	1073.1	(1)	927	7	(3)			894.4	(4)
	93188		107794					111807	
3.	1028.7	(10)	894	4	(4)				
	97210		111807						
4.	908.5	(0)	802	07					
	110072		124677						
5.	888.5	(3)	786	5.48	(1)				
	112549		127149	)					
6.	860.6	(())	764	57	(2)				
	116200		130792	2					
7.	840.99	(5)	749	9.09	(3)				
	118908		133495	<b>,</b>	•				
8.	802.03	(5)	718	8.07	(2)				
	124684	•	139262	2	. ,				

Triplet number 7 is identified by Smith, recently as  $1^{s}P-2^{s}S$ ; but the line 137491 classified by him as  $1^{s}P_{0}-2^{s}S_{1}$  is not recorded either by Carroll or Mack.

#### Spectrum of Pb. IV.

The first successful attempt to find series regularities among the wavelengths of trebly—ionised spectrum of lead, was that made by Carroll<sup>8</sup>, who identified the first members of the principal and diffuse series occurring in the vacuum grating region. In a recent communication<sup>16</sup>, the present writer set forth the leading members of the secondary series, which may be expected in the region of longer wavelengths.

The term structure of the spectrum of Pb. IV is generally similar in character to that of any chemically analogous atom or ion. Of these the spectra of Au I, Hg II and Tl. III and those of Ge IV and Sn IV have already been analysed to some extent. We have in the atom of Pb. IV, a one electron system, which normally gives the simplest type of alkali-like doublet spectrum. As the electron runs successively through P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>,  $Q_1$  . . . shells, the terms 1, <sup>2</sup>S, 1 <sup>2</sup>P, 1 <sup>2</sup>D, 2 <sup>2</sup>S, etc., are obtained, the largest term being 1 <sup>2</sup>S<sub>1</sub>. The more complicated scheme of doublets and quartets result, when one or more of the inner group of 10 O<sub>3</sub>, electrons is excited. The terms which different electron configurations give rise to may be calculated according to the principles developed by Pauli, Heisenberg & Hund and are given in the following table. It will be seen from the table that corresponding to the addition of an electron to the three different states ('S, \*D, 'D) of the Pb V core, three distinct families of terms arise.

KLMN	0					Р			Term	Terms predicted.	Series limit
1 <sub>1</sub> 4 <sub>4</sub>	51	52	58	54	55	61	62	6 <sub>3</sub>	prefix.		Pb V term.
60 60 60 60 60	2 2 2 2 2 2 2 2 2	6 6 6 6 6	$ \begin{array}{c c} 10 \\ 10 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9$	1		(1) 1(1) 1	(1) (1)	(1) (1)	68 6p 6d 6p <sup>1</sup> 6d <sup>1</sup>	<sup>2</sup> S <sup>2</sup> P <sup>2</sup> D <sup>4</sup> P D F <sup>2</sup> P D F <sup>2</sup> P D F <sup>1</sup> <sup>4</sup> S P D F G <sup>2</sup> S P D F G <sup>2</sup> S P D F G <sup>1</sup>	<sup>1</sup> S <sup>8</sup> D <sup>1</sup> D

TABLE XVII.

The analysis of Cu I Zn II Au I & Hg II has shown that in addition to the regular doublet systems built on the d<sup>0</sup> ion there is another important family of terms bu lt on the d<sup>9</sup>s ion characterized by doublet and quartet terms The deepest term of this system is a metastable D term which is inverted and very low The separation of this deep lying  $D(d^{9}s)$  term can be found approximately by the relativistic doublet formula and by a knowledge of the D (d<sup>9</sup>s) difference of the next higher ion As both these sources of nformation were available att mpts were made to ident fy this inverted D term Further in Cu I Zn II Au I etc The metastable D term s found to combine strongly with the regular P term (d p) and with the quartet terms a using from the d<sup>9</sup>sp configuration The recent analysis of the second spark spect um of Thallium by the author has shown that these terms are tound in the spectrum of TI III" After the publication of the above mentioned report by the writer Smith published a preliminary report of a similar inv stigation where he suggests an alternative classification which without adducing any reasons From the application of the relativistic doublet law to isoelectronic specire he mentions as more p obabl (Au I Hg II Th III and Pb IV) and from a study of the progressive variation  $\Delta$  Z in the homologous spectra C IV S IV Ge IV & Sn IV it was thought from the biginning of this investigation that (2\*P,-2\*P) should be of the ord r of 7  $000\pm600$  With the aid of the information available to the author regarding the stages of ionisation of the spectral lines in the visible and quartz regions a search was made for the frequency recurrence among the Pb IV I nes and it was found that there were three alternative schemes as constituting the probable doublet systems with (2 P - 2 P) = 6838 7131 8063 respectively. It is the pairs of the wavelengths with the last mentioned frequency difference that were given by Smith as the more probable Relativity doublet sequence and progression of  $\frac{\Delta}{Z}$  for the doublet separations are given in Tables XXI

and XX The doublet systems classified by the write are given in Table XXI

TABLE	XVIII — PAIRS	<b>H</b> TIW	FREQUENCY	DIFFLRENCI 9
6838		7131		8063
24139		23903		2468.
30979		31037	,	32749
26730		25573	}	°5229
<b>3</b> 3567		32704	l.	33294
32362		34032	}	31780
39200		41162	3	39847
33007		36325	5	32548
39847		43458	1	40613

TABLE XIX -REGULAR	DOUBLET	SEQUENCE
--------------------	---------	----------

	1 P <sub>12</sub>	*∕∆	2 P <sub>12</sub>	\$∕∧
Au I	3815	7 859		
Hg II	91227	9 773	3672	7 76
TI III	14811	11 031	5682	8 60
Pb IV	21060	12 047	7130	9 17

TABLE XX	OF	DOUBLET	SEPARATION	WITH	L
----------	----	---------	------------	------	---

At. N Z	kleme t	2P2 P	∆ /Z³	1P —1P	$\wedge  \mathbf{Z} $
6	C IV			107 4	2 983
14	Si IV	162	826	460 0	2 847
32	Ĝe IV	942	92	2790	2 726
50	Sn IV	2177 4	871	6507	2 602
82	Pb IV	7130	10	21060	3 130

,	L'ABLE XX	1.—Dou	BLET	SYSTEMS	OF Pb. IV	•
		λ			ν	
$1^{2}S_{1}-1^{2}P_{1}$		1313.2	(9)		76150)	91060
1°P2		1028.7	(10)		97210 <sup>5</sup>	21000
$1^{s}P_{2}-1^{2}D_{2}$		11450	(3)		ر 87336 ر	
$-1^{2}D_{8}$		1116.2	(4)		89590 {	21065
$1^{2}P_{1}-1^{2}D_{2}$		922.5	(4)		108401	2201
1P-22S	J	123.45	(3)		89012	91055
$1^{2}P_{1}-2^{2}S_{1}$		908.54	(5)		110067	21000
$2^{2}S_{1}-2^{2}P_{1}$		4182.40	(8s)		23903)	7122
$-2^{2}P_{2}$		3221.00	(10)		<sub>31037</sub> ∫	00
$1^{2}D_{2}$ — $2^{2}P_{1}$		3909 <sup>.</sup> 29	(5d)		25573	
<sup>2</sup> D <sub>3</sub> — P <sub>2</sub>		3280.09	(9)		30478	7131 9996
<sup>9</sup> D <sub>2</sub> P <sub>2</sub>		3056.84	(4)		$_{32704}$ )	2220
2°P2°D <sub>2</sub>		2937.55	(4)		34032	~
D8		2864.45	(10)		34900	868
$2^{2}P_{1} - D_{2}$		2 <b>42</b> 8·70	<b>(</b> 8bd)		41162 <b>)</b>	1100
$2^{*}P_{2}$ — $3^{2}S_{1}$		2752.15	(1)		36325 \	7122
$P_1 - 3^2 S_1$		2300.32	(4s)		$_{43458}$	1199
$2^{2}D_{2}-2^{2}F_{3}$		3483.46	(9)		28699)	875
$D_3 - F_3$		3592.95	(6s)		27824	010

In the first place it should be mentioned that 8,063 given by Smith as 2  ${}^{2}P_{12}$  is found to be abnormally high from the relativistic doublet sequence and from the progressive variation of  $\Delta \nu/Z^{2}$  in the homolagous spectra, as shown in the preceding tables. Further, justification for the difference 7130, reported by the author is afforded by the location and identification of the following triplet as 6s<sup>1</sup> <sup>2</sup>D-7p <sup>3</sup>P.

#### TABLE XXII.

(l <sup>10</sup> p/d <sup>9</sup> s <sup>2</sup>	$^{2}\mathrm{D}_{8}$	21019	<sup>2</sup> D <sub>2</sub> .
$^{2}P_{1}$			804.55 (1)
(7130)			124293
$^{2}P_{2}$	655.82(3)		760.90 (0)
	152439		131420

There is no evidence of a similar combination with (ither of the remaining two separations. That the difference  $21019 \text{ cm}^{-1}$  represents the difference  ${}^{2}D_{s}^{---} {}^{2}D_{2} (d^{9}s^{2})$  of Pb. IV seems to be confirmed by the following comparison with  ${}^{8}D_{18}$  (d<sup>9</sup>s) of the next higher ion.

#### TABLE XXIII. T). $\mathbf{Pb}_{ullet}$ Cd. Cu. Ag. Zn. 21300(?)d<sup>9</sup>s 1886557642070 4574 2754d<sup>9</sup>s² 21019 56351861820434472 2719

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The combinations of this deep lying inverted D term with the quartet terms of the group (d<sup> $\theta$ </sup>sp) are given in the following table —

	TABLE XXIV	
6p /6	מ	D
4F		1407 8 (1)
		71033
F	1749 9 (1)	1279 5 (3)
	5714b	78167
F	1439 2 <b>(</b> 2)	11048 (od)
	69478	90510
D		1308 2 (2)
		76441
D	1437 1 (1d)	11036 (od)
	69585	90613
D	<b>1233</b> 6 (3)	979 47 (2)
	81068	102096
D	1096 5 (1d)	
	91189	
 ⁴₽	1362 60 (0)	10593 (1)
	73381	94400
P	1087 34 (2)	884 98 (6)
P	91968	112997

#### Summary and conclusions 1

The spark spectrum of Lead has been photographed from  $\lambda$ 7000 to  $\lambda$ 2000 by using powerful  $\dots$  climitary with a quartz spectrograph and a 10 feet concave grating using iron arc as the standard Many new limit have been measured mostly produced by the higher stages of ionisation. The wave numbers wavelengther intensities together with the stages of ionisation of the prominent ones have been tabulated

A critical differentiation of the lines belonging respectively to Pb I Pb II Pb III Pb IV resulted from a careful scrutiny of the spectra obtained under varying degrees of excitation

The analysis of the second and third spark spectra of the element has been discussed in relation to the theoretical expectations and with the accurate and extensive data at hand it has been shown that the succurastructures of Pb III and Pb IV are in all details in complete agreement with Hund's correlation of specific terms with electron onfigurations

The present analysis illustrates in a very convincing manner the utility of the study of the spectra of an element under varying degrees of discharge

In conclusion I wish to express my gratitude to Dr T Royds the Director of the Kodajkanal Ober vatory and to Dr A. I. Narayan the Assistant Director for their active interest and much helpful criticist throughout the progress of the work My thanks are also due to the Syndicate of the Madres University for the award of a studentship which has made this work possible 261

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#### Explanation of plates.

I and II Spark Spectra of Lead, Concave Grating Spectrograph. III and IV Spark Spectra of Load, Quartz Spectrograph, with increasing inductance a, b, c, d.

KODAIKANAL, 22nd December 1930. A. S. RAO, Research Scholar.

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