III. *On the Ultra-Violet Spectra of the Elements.*—Part I. *Iron* (*with a map*).

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[Plates 1–5.]

Ångström's "normal solar spectrum" has served most spectroscopists as a standard of reference for wave-lengths in the visible part of the spectrum. Cornu's continuation of it, and particularly the map of the iron lines which he used in the construction of it, serves very well for such a standard up to the limit of the solar spectrum, *i.e.*, to a wave-length 2948 (U). For the region above this we have had to use Mascart's and Cornu's wave-lengths of the cadmium lines, and Cornu's wave-lengths of some magnesium lines. The intervals between those lines are, however, too great for any close approximation to the wave-lengths of intervening lines by interpolation, and, moreover, the wave-lengths did not appear to be determined with sufficient precision to serve as a standard, and the lines are ill adapted to that purpose by reason of their diffuse character. For the determination of the wave-lengths of lines in this higher region we have, therefore, been driven to form a standard for ourselves. For this purpose we have chosen the iron spectrum which had been employed by Cornu in the region which he mapped, and seemed to answer the purpose well, both from the number of lines which it presents and their characteristic grouping by which they may easily be recognised by anyone who has once become familiar with them. The wave-lengths of the most prominent lines were determined by means of a Rutherfurd diffraction grating, as detailed below, between the wave-lengths 2948 and 2327; but beyond this there is a remarkable falling off in the intensity of the iron lines, and between wave-lengths 2327 and 2135 (which is near the limit of transparency of Iceland spar) we have preferred to determine the wave-lengths of the prominent copper lines which are numerous and strong in that region. The wave-lengths of a series of lines at short intervals having thus been determined, those of the intervening lines were obtained by interpolation, and the result is shown in the map of the iron spectrum above U which accompanies this paper.

The instruments.

The goniometer used was constructed for us by HILGER, and has a circle of 18 inches diameter, graduated at intervals of 5′ by SIMMS. Fractions of 5′ are read by a microscope with a micrometer eye-piece fixed to the arm which carries the telescope.

The telescope and collimator have each an object-glass consisting of a single lens of quartz $1\frac{1}{2}$ inch diameter and a focal length of $18\frac{1}{2}$ inches for the sodium yellow light, but not more than 16 inches for the highest rays measured. The sliding tubes of both telescope and collimator are graduated in fiftieths of an inch, and alterations of focus were made on both instruments at the same time, so that the rays falling on the grating might always be nearly parallel. The graduation of the sliding tube was also used for ascertaining the distance of the photographic plate from the object-glass of the telescope. This was necessary for computing the corrections of the angular measure, as explained below. The collimator is furnished with a quartz lens, of 3 inches focal length, in front of the slit, movable to a greater or less distance, but retained by guides so that its axis may remain coincident with that of the collimator. This lens was placed about 6 inches in front of the slit, and the source of light at the same distance beyond it, so that its image was focussed on the slit.

The measurements were all made by means of photographs taken on WRATTEN and WAINWRIGHT's instantaneous dry gelatine plates. The plates ($2\frac{1}{4}$ inches by 1 inch) were held in a small slide attached to a tube which fitted the telescope in place of the eye-piece, and thus the plate could easily be turned about an axis perpendicular to its plane and coinciding with the axis of the telescope. This turning of the plate about is a matter of no small importance, as it enabled us to avoid the errors which would have arisen from measuring the distances of the lines from the irregular edge of the plate, as will be seen when the mode of measuring the photographs is described. The plates were retained in one position in the slide during exposure by three springs, of which two pressed against two edges of the plate and the other against its back.

The grating was ruled on speculum metal by CHAPMAN with RUTHERFURD's machine, and has a ruled surface of rather more than $1\frac{3}{4}$ inch in each dimension, with 17,296 lines to the inch. It is an excellent grating, but, of course, has the faults which belong to the particular machine by which it was ruled. The definition, when it has not been exposed to variations of temperature, is very good, but it has one inconvenience for our present purpose, which is, that the focus for the same ray in the spectrum of the same order does not fall at quite the same distance from the object-glass of the telescope on the two sides of the normal. The explanation of this has been given by CORNU (Comptes Rendus, lxxx., 645), who has shown that it is due to a systematic variation in the distance between the ruled lines. As the method employed by us depends upon taking angular measures of the position of the ray on both sides of the normal, and any shift of the focussing tube between the two positions would be likely to introduce serious errors, we have been obliged to be content with the photograph taken on one side being a little, though only a little, less sharp in definition than that taken on the other side. The grating was used with its plane perpendicular to the axis of the collimator, and it was brought into that position in the following way. The telescope and collimator having their axes directed as nearly as possible on to the centre of the circle, the telescope was placed opposite the collimator and the cross wires brought on to the image of the slit, and the reading of the circle taken. The grating was then placed in position and adjusted for level until the spectra occupied the middle of the field of view in all positions of the telescope. It was then adjusted in azimuth until the images of the D lines, from the light of a sodium flame in front of the slit, in the spectra of the second order, on the two sides of the normal were at equal angular distances from the axis of the collimator, as determined by the reading taken when the telescope was opposite the collimator. The grating was then clamped in that position. This adjustment had to be made by hand and was liable to disturbance in the clamping, so that it was afterwards found that the plane of the grating was not quite perpendicular to the axis of the collimator; but as the errors arising from this in the measures on the two sides nearly compensate one another, the final error in the wave-length from this cause is very small indeed.

For measuring the photographs a micrometer was constructed for us by HILGER. This is attached to the stage of a microscope and carries a small frame in which the photographic plate is held by springs. The micrometer-screw has 100 turns to the inch, and by the drum-head $\frac{1}{100}$th of a turn or $\frac{1}{10000}$th of an inch can be read. A 1 inch object-glass to the microscope was used, and measures were made by moving the plate until the lines of the photograph were successively bisected by a spider line in the eye-piece. The reading of the micrometer gave the distances between the lines.

The source of light employed was, in the first instance, the arc from a DE MERITENS magneto-electric machine, in a crucible of magnesia into which iron wire was introduced. But from the overlapping of the spectra of different orders, and the large amount of light emitted by the arc, we found that the plates were so clouded in many places that the lines could not be well seen, and we abandoned the arc for the spark between iron electrodes. This was produced by a large induction coil, worked by 5 GROVE's cells, and having a large Leyden jar connected with the secondary wire. No inconvenience arose from the overlapping of the different orders when the spark was used, because the parts of the spectra of higher and lower orders which overlapped the part of the spectrum of the fourth order to be measured were always considerably out of focus, the object glasses of telescope and collimator being uncorrected, and so the light of the lines in the overlapping spectra was diffused and produced only a faint clouding of the plate, which in no way interfered with the measure of the lines of the fourth order.

Mode of proceeding.

The first thing to be done was to obtain a focussing scale for the different angles, including the portion of the spectrum to be mapped. This was already known approximately from SARASIN's table of refractive indices of quartz, and was corrected by a series of trial plates taken at successive angles.

The electrodes, between which the spark was passed, were arranged so that the spark should pass horizontally (the slit being vertical), and at such a height that the visible image formed by the lens in front of the slit on the plates of the slit might fall just above, or partly above, the centre of the slit. The lower half of the slit was closed by a shutter, so that only the lower half of the field of view of the telescope was illuminated. The distance of the spark from the lens had next to be adjusted, as the focal length of the lens for the visible rays is very different from that for the ultra-violet which were to be photographed. This was done by estimation, as there was no need to have the image exactly focussed on the slit, so long as the slit was in the middle of the image and light enough passed through.

The telescope was then set to such an angle as would bring the line so measured nearly into the centre of the field, the focus adjusted, the photographic slide adjusted and levelled, and the plate exposed. An image of the lines was thus formed on the lower half of the plate. The slide was then turned round through 180° about the axis of the tube, so as to bring what had before been the upper side of the plate to the lower side and right to left, and again levelled. The plate was then again exposed and thus a second image of the line impressed, and one of the two images was as far to the right of the axis about which the plate had been turned as the other was to the left. Half the distance between the two images would therefore be the distance of the line from the centre of the field, and the knowledge of this would give the means of calculating the deviation of the rays producing the line from the axis of the telescope. The telescope was next turned to the corresponding angle on the other side of the collimator and the operations repeated with a second plate, but without any alterations of adjustment. The telescope was then moved through a small angle, generally 5′ or 10′, and the same operations as before repeated on both sides of the collimator, the second pair of plates being intended to serve as a check upon the first.

Similar operations were then repeated at such angular intervals as should bring in the most characteristic strong lines of iron all along the scale. Beyond the wave-length 2327, it was found that the iron lines were too faint to produce any sufficient impression on the plates. For the region beyond this up to wave-length 2135, copper electrodes were substituted for iron. This being about the limit of transparency of calcite (the material of our prisms), was the limit of our study of spectra at this time.

The measurement of the distance between the two images of a line was made by the micrometer above described, and to convert this distance into arc, it was necessary to know the distance of the plate from the centre of the object-glass of the telescope. It was found by measurement that the distance from the object-glass to the front of the photographic plate, when the sliding tube was at the 100th division, was 439 millims., and the thickness of the lens at its middle 2·5 millims., which, divided by the refractive index of quartz for the high rays observed is very nearly 1·5 millim., making the distance of the photographic plate from the optical centre of the object-glass very nearly 440·5 millims. From this the formula $\tan^{-1}\frac{D}{3068{\cdot}5+4a}$ was deduced for the angular distance of a line from the axis of the telescope when the difference of the micrometer readings of the two images of the line is D, and the number of divisions of the scale of sliding tube at which the telescope was focussed was a. To determine whether the angle so found was to be added or subtracted from the reading of the circle, all that was necessary was to observe whether the micrometer reading of the upper or lower image as seen in the microscope were the greater. The angular position of the line having thus been found on each side of the collimator, the wave-length was deduced by the ordinary formula.

The following tables give the measurements made, the calculated angles, and the wave-lengths deduced.

The quantities recorded in the several columns is as follows :—

I. The mark of the particular photographic plate.

II. The reading of the circle, giving the position of the telescope.

III. The reading of the scale of focussing tube.

IV. The measured distance of the two images of the line in hundredths of an inch.

V. One half this distance reduced to angular measure with the sign + or − according as it is to be added or subtracted from the reading of the circle to give the angular position of the line.

VI. The angular position of the line.

VII. The mean values of the angular positions so found. When several sets of plates have been taken at different times, or with varied adjustments, the means for the several sets are given separately.

VIII. The deviation from the normal to the grating of the line as deduced.

IX. The wave-length deduced or adopted. When different sets of plates give different values, these different values are inserted in brackets.

The figures belonging to different lines are separated by horizontal spaces.

In the case of plates marked with a figure less than 172 the arc was employed to give the light, in the case of all plates with the mark 172 and upwards the spark was employed.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
341	28 30 0	49	10·63	−11 12	28 18 48			
342	309 30 0	49	8·43	+ 8 53	309 38 53			
343	309 25 0	49	13·39	+14 6	309 39 6	309 39 0	39 19 54	2326·9
341	28 30 0	49	6·11	− 6 26	28 23 34			
342	309 30 0	49	3·96	+ 4 10	309 34 10			
343	309 25 0	49	8·72	+ 9 11	309 34 11		39 24 42	2330·9
341	28 30 0	49	4·36	− 4 35	28 25 25			
342	309 30 0	49	2·01	+ 2 7	309 32 7			
343	309 25 0	49	6·92	+ 7 17	309 32 17	309 32 12	39 26 36	2332·5
341	28 30 0	49	1·64	+ 1 44	28 31 44			
342	309 30 0	49	3·96	− 4 10	309 25 50			
343	309 25 0	49	0·87	+ 0 55	309 25 55	309 25 52	39 32 56	2337·7
341	28 30 0	49	7·92	+ 8 20	28 38 20			
342	309 30 0	49	10·37	−10 55	309 19 5			
343	309 25 0	49	5·57	− 5 52	309 19 8	309 19 6	39 39 37	2343·2
341	28 30 0	49	8·78	+ 9 15	28 39 15			
342	309 30 0	49	11·27	−11 52	309 18 8			
343	309 25 0	49	6·36	− 6 42	309 18 18	309 18 13	39 40 31	2343·9
341	28 30 0	49	13·40	+14 7	28 44 7			
342	309 30 0	49	15·89	−16 44	309 13 16			
343	309 25 0	49	11·07	−11 39	309 13 21	309 13 14	39 45 27	2348·0
262	28 45 0	50	11·67	+12 16	28 57 16			
263	28 40 0	50	16·38	+17 14	28 57 14	28 57 15		
264	309 15 0	50	13·97	−14 42	309 0 18			
265	309 10 0	50	9·18	− 9 39	309 0 21	309 0 19	39 58 28	2358·7
262	28 45 0	50	12·91	+13 35	28 58 35			
263	28 40 0	50	17·63	+18 33	28 58 33	28 58 34		
264	309 15 0	50	15·15	−15 56	308 59 4			
265	309 10 0	50	10·44	−10 59	308 59 1	308 59 2	39 59 46	2359·7
262	28 45 0	50	18·33	+19 17	29 4 17			
263	28 40 0	50	23·02	+24 13	29 4 13	29 4 15		
264	309 15 0	50	20·68	−21 45	308 53 15			
265	309 10 0	50	15·98	−16 48	308 53 12	308 53 13	40 5 31	2364·4
81	29 30 3	25	1·70	+ 1 51	29 31 54			
82	29 30 3	25	2·02	+ 2 12	29 32 15			
86	29 34 3	25	2·37	− 2 35	29 31 28	29 31 52		
84	308 59 40	25	1·52	− 1 39	308 58 1			
85	308 59 40	25	1·20	− 1 18	308 58 22	308 58 12	40 16 50	(2373·7)
100	308 53 50	25	2·47	− 2 41	308 51 9			
101	308 53 50	25	2·66	− 2 53	308 50 57	308 51 3		
102	29 40 0	25	14·64	−15 53	29 24 7			
103	29 30 0	25	5·40	− 5 52	29 24 8	29 24 7	40 16 32	2373·4
262	28 45 0	50	28·65	+30 8	29 15 8			
263	28 40 0	50	33·33	+35 3	29 15 3	29 15 6		
264	309 15 0	50	31·09	−32 42	308 42 18			
265	309 10 0	50	26·36	−27 43	308 42 17	308 42 17	40 16 25	(2373·3)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
262	28 45 0	50	38·19	+40 10	29 25 10			
263	28 40 0	50	42·96	+45 11	29 25 11	29 25 11		
264	309 15 0	50	40·87	−42 59	308 32 1			
265	309 10 0	50	36·11	−37 59	308 32 1		40 26 35	(2381·6)
81	29 30 3	25	11·29	+12 14	29 42 17			
82	29 30 3	25	11·62	+12 36	29 42 39			
86	29 34 3	25	7·13	+ 7 44	29 41 47	29 42 14		
84	308 59 40	25	11·02	−11 57	308 47 43			
85	308 59 40	25	10·82	−11 44	308 47 56	308 47 48	40 27 13	(2382·1)
100	308 53 50	25	12·00	−13 1	308 40 49			
101	308 53 50	25	12·26	−13 18	308 40 32	308 40 40		2381·7
102	29 40 0	25	5·27	− 5 43	29 34 17			
103	29 30 0	25	4·10	+ 4 27	29 34 27	29 34 22	40 26 51	(2381·8)
258	308 15 0	53	16·34	+17 7	308 32 7			
259	308 20 0	53	11·86	+12 26	308 32 26	308 32 17		
260	29 45 0	53	18·78	−19 41	29 25 19			
261	29 40 0	53	13·70	−14 21	29 25 39	29 25 29	40 26 36	(2381·6)
81	29 30 3	25	18·96	+20 34	29 50 37			
82	29 30 3	25	19·14	+20 55	29 50 58			
86	29 34 3	25	14·66	+15 54	29 49 57	29 50 31		
84	308 59 40	25	18·66	−20 15	308 39 25			
85	308 59 40	25	18·45	−20 1	308 39 39	308 39 32	40 35 29	(2388·8)
258	308 15 0	53	8·56	+ 8 58	308 23 58			
259	308 20 0	53	4·01	+ 4 12	308 24 12	308 24 5		
260	29 45 0	53	11·02	−11 33	29 33 27			
261	29 40 0	53	5·89	− 6 10	29 33 50	29 33 38	40 34 46	(2388·2)
100	308 53 50	25	19·61	−21 17	308 32 33			
101	308 53 50	25	19·77	−21 27	308 32 23	308 32 28		
102	29 40 0	25	2·31	+ 2 30	29 42 30			
103	29 30 0	25	11·64	+12 38	29 42 38	29 42 34	40 35 3	2388·5
100	308 53 50	25	27·60	−29 57	308 23 53			
101	308 53 50	25	27·79	−30 9	308 23 4	308 23 47		
102	29 40 0	25	10·33	+11 12	29 51 12			
103	29 30 0	25	19·64	+21 18	29 51 18	29 51 15	40 43 44	(2395·5)
258	308 15 0	53	0·22	+ 0 14	308 15 14			
259	308 20 0	53	4·41	− 4 37	308 15 23	308 15 18		2395·4
260	29 45 0	53	2·85	− 3 3	29 41 57			
261	29 40 0	53	2·20	+ 2 18	29 42 18	29 42 7	40 43 24	(2395·2)
100	308 53 50	25	31·80	−34 30	308 19 20			
101	308 53 50	25	32·03	−34 45	308 19 5	308 19 12		
102	29 40 0	25	14·46	+15 41	29 55 41			
103	29 30 0	25	23·85	+25 53	29 55 53	29 55 47	40 48 18	(2399·2)
258	308 15 0	53	4·16	− 4 22	308 10 38			
259	308 20 0	53	8·65	− 9 4	308 10 56	308 10 47		2399
260	29 45 0	53	1·45	+ 1 31	29 46 31			
261	29 40 0	53	6·53	+ 6 51	29 46 51	29 46 41	40 47 57	(2398·9)
258	308 15 0	53	10·89	−11 25	308 3 35			
259	308 20 0	53	15·48	−16 13	308 3 47	308 3 41		
260	29 45 0	53	8·08	+ 8 28	29 53 28			
261	29 40 0	53	13·13	+13 46	29 53 46	29 53 37	40 54 58	2404·5

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
258	308 15 0	53	12·97	−13 36	308 1 24			
259	308 20 0	53	17·53	−18 22	308 1 38	308 1 31		
260	29 45 0	53	10·18	+10 40	29 55 40			
261	29 40 0	53	15·18	+15 54	29 55 54	29 55 47	40 57 8	2406·3
258	308 15 0	53	17·57	−18 25	307 56 35			
259	308 20 0	53	22·12	−23 11	307 56 49	307 56 42		
260	29 45 0	53	14·65	+15 21	30 0 21			
261	29 40 0	53	19·69	+20 38	30 0 38	30 0 30	41 1 54	2410·2
258	308 15 0	53	18·20	−19 4	307 55 56			
259	308 20 0	53	22·79	−23 53	307 56 7	307 56 1		
260	29 45 0	53	15·41	+16 9	30 1 9			
261	29 40 0	53	20·35	+21 20	30 1 20	30 1 15	41 2 37	2410·7
258	308 15 0	53	20·93	−21 56	307 53 4			
259	308 20 0	53	25·55	−26 46	307 53 14	307 53 9		
260	29 45 0	53	17·99	+18 51	30 3 51			
261	29 40 0	53	23·01	+24 7	30 4 7	30 3 59	41 5 25	2413·0
254	30 45 0	57	7·82	− 8 9	30 36 51			
255	30 40 0	57	3·05	− 3 11	30 36 49	30 36 50		
256	307 15 0	57	5·71	+ 5 57	307 20 57			
257	307 20 0	57	1·06	+ 1 6	307 21 6	307 21 2	41 37 54	2439·0
254	30 45 0	57	1·60	− 1 40	30 43 20			
255	30 40 0	57	3·17	+ 3 18	30 43 18	30 43 19		
256	307 15 0	57	0·67	− 0 42	307 14 18			
257	307 20 0	57	5·37	− 5 36	307 14 24	307 14 21	41 44 29	2444·3
254	30 45 0	57	0·27	− 0 17	30 44 43			
255	30 40 0	57	4·45	+ 4 38	30 44 38	30 44 41		
256	307 15 0	57	1·98	− 2 4	307 12 56			
257	307 20 0	57	6·70	− 6 59	307 13 1	307 12 58	41 45 52	2445·4
250	32 0 0	65	47·16	−48 42	31 11 18			
251	306 5 0	65	40·20	+41 31	306 46 31		42 12 23	2466·4
250	32 0 0	65	42·39	−43 47	31 16 13			
251	306 5 0	65	35·41	+36 34	306 41 34		42 17 19	2470·3
250	32 0 0	65	30·79	−31 48	31 28 12			
253	31 45 0	65	16·06	−16 35	31 28 25	31 28 18		
251	306 5 0	65	23·53	+24 18	306 29 18			
252	306 15 0	65	13·80	+14 15	306 29 15	306 29 17	42 29 31	2480·0
250	32 0 0	65	28·43	−29 22	31 30 38			
253	31 45 0	65	13·78	−14 14	31 30 46	31 30 42		
251	306 5 0	65	21·27	+21 58	306 26 58			
252	306 15 0	65	11·42	+11 48	306 26 48	306 26 53	42 31 54	2481·8
250	32 0 0	65	27·73	−28 38	31 31 22			
251	306 5 0	65	20·52	+21 12	306 26 12		42 32 35	2482·4
71	31 54 45	50	3·07	− 3 14	31 51 31			
72	306 38 55	50	5·78	+ 6 5	306 45 0			
73	306 38 55	50	5·79	+ 6 5	306 45 0	306 45 0	42 33 15	2482·9

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
71	31 54 45	50	2·04	− 2 9	31 52 36			
72	306 38 55	50	4·77	+ 5 1	306 43 56			
73	306 38 55	50	4·85	+ 5 6	306 44 1	306 43 59	42 34 18	2483·7
250	32 0 0	65	23·27	−24 2	31 35 58			
253	31 45 0	65	8·35	− 8 37	31 36 23	31 36 10		
251	306 5 0	65	16·24	+16 46	306 21 46			
252	306 15 0	65	6·02	+ 6 13	306 21 13	306 21 30	42 37 20	2486·1
107	306 10 10	50	17·40	+18 18	306 28 28			
108	306 0 0	50	27·46	+28 53	306 28 53			
109	306 10 10	50	17·71	+18 36	306 28 46			
110	306 20 0	50	8·64	+ 9 6	306 29 6	306 28 48		
111	32 0 5	50	11·83	−12 27	31 47 33			
112	32 0 5	50	12·02	−12 39	31 47 26	31 47 33	42 39 23	2487·7
113	31 50 10	50	2·39	− 2 31	31 47 39			
71	31 54 45	50	4·74	+ 4 59	31 59 44			
72	306 38 55	50	2·06	− 2 10	306 36 45			
73	306 38 55	50	2·08	− 2 11	306 36 44	306 36 44	42 41 30	(2489·4)
172	31 50 5	50	2·00	− 2 6	31 47 59			
173	31 40 20	50	7·41	+ 7 48	31 48 8			
174	32 0 5	50	11·67	−12 16	31 47 49	31 47 59		
175	306 23 0	50	1·04	+ 1 6	306 24 6			2489·5
176	306 33 5	50	8·37	− 8 48	306 24 17			
177	306 13 0	50	10·74	+11 18	306 24 18	306 24 14	42 41 53	(2489·7)
250	32 0 0	65	19·12	−19 45	31 40 15			
253	31 45 0	65	4·34	− 4 29	31 40 31	31 40 23		
251	306 5 0	65	11·64	+12 1	306 17 1			
252	306 15 0	65	1·79	+ 1 54	306 16 54	306 16 57	42 41 43	2489·5
250	32 0 0	65	17·91	−18 30	31 41 30			
253	31 45 0	65	3·12	− 3 13	31 41 47	31 41 38		
251	306 5 0	65	10·51	+10 51	306 15 51			
252	306 15 0	65	0·73	+ 0 45	306 15 45	306 15 48	42 42 55	2490·5
250	32 0 0	65	14·87	−15 21	31 44 39			
253	31 45 0	65	0·09	− 0 6	31 44 54	31 44 46		
251	306 5 0	65	7·42	+ 7 40	306 12 40			
252	306 15 0	65	2·41	− 2 29	306 12 29	306 12 35	42 46 5	2493·0
172	31 50 5	50	2·19	+ 2 18	31 52 23			
173	31 40 20	50	11·59	+12 11	31 52 31			
174	32 0 5	50	7·55	− 7 56	31 52 9	31 52 21		
175	306 23 0	50	3·19	− 3 22	306 19 38			2493·0
176	306 33 5	50	12·59	−13 15	306 19 50			
177	306 13 0	50	6·53	+ 6 52	306 19 52	306 19 47	42 46 17	(2493·1)
246*	305 20 0	65	51·22	+52 54	306 12 54			
247	305 25 0	65	46·37	+47 53	306 12 53	306 12 54		
248	32 45 0	65	58·23	−60 8	31 44 52			
249	32 40 0	65	53·28	−55 1	31 44 59	31 44 55	42 46 0	(2492·9)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
246*	305 20 0	65	44·18	+45 38	306 5 38			
247	305 25 0	65	39·34	+40 38	306 5 38			
248	32 45 0	65	51·14	−52 49	31 52 11			
249	32 40 0	65	46·31	−47 50	31 52 11		42 53 16	(2498·6)
172	31 50 5	50	8·97	+ 9 26	31 59 31			
173	31 40 20	50	18·45	+19 24	31 59 44			
174	32 0 5	50	0·64	− 0 40	31 59 25	31 59 33		
175	306 23 0	50	10·13	−10 39	306 12 21			2498·7
176	306 33 5	50	19·56	−20 34	306 12 31			
177	306 13 0	50	0·42	− 0 27	306 12 33	306 12 30	42 53 32	(2498·8)
91	306 39 0	50	26·86	−28 15	306 10 45			
92	31 55 0	50	24·04	+25 17	32 20 17			
93	31 55 0	50	23·92	+25 10	32 20 10	32 20 14	43 4 45	2507·6
181	305 22 0	55	33·07	+34 34	305 56 34	305 56 34		
182	32 56 10	55	38·61	−40 22	32 15 48			
183	32 55 5	55	37·47	−39 10	32 15 55			
184	32 51 15	55	33·88	−35 25	32 15 50			
185	32 35 2	55	18·40	−19 14	32 15 48			
186	32 25 15	55	9·02	− 9 26	32 15 49	32 15 50	43 9 38	2511·4
246*	305 20 0	65	28·14	+29 4	305 49 4			
247	305 25 0	65	23·20	+23 54	305 48 54	305 48 59		
248	32 45 0	65	35·35	−36 31	32 8 29			
249	32 40 0	65	30·54	−31 33	32 8 27	32 8 28	43 9 44	2511·4
246*	305 20 0	65	10·95	+11 19	305 31 19			
247	305 25 0	65	5·97	+ 6 10	305 31 10	305 31 15		
248	32 45 0	65	18·43	−19 2	32 25 58			
249	32 40 0	65	13·56	−14 0	32 26 0	32 25 59	43 27 22	(2525·2)
181	305 22 0	55	16·10	+16 50	305 38 50	305 38 50		
182	32 56 10	55	22·02	−23 1	32 33 9			
183	32 55 5	55	20·82	−21 46	32 33 19			
184	32 51 15	55	17·24	−18 1	32 33 14			
185	32 35 2	55	1·72	− 1 48	32 33 14			
186	32 25 15	55	7·69	+ 8 2	32 33 17	32 33 15	43 27 13	2525·1
246*	305 20 0	65	9·81	+10 8	305 30 8			
247	305 25 0	65	4·84	+ 5 0	305 30 0	305 30 4		
248	32 45 0	65	17·35	−17 55	32 27 5			
249	32 40 0	65	12·48	−12 53	32 27 7	32 27 6	43 28 31	2526·1
246*	305 20 0	65	5·72	+ 5 54	305 25 54			
247	305 25 0	65	0·78	+ 0 48	305 25 48	305 25 51		
248	32 45 0	65	13·25	−13 41	32 31 19			
249	32 40 0	65	8·32	− 8 36	32 31 24	32 31 22	43 32 45	(2529·3)
178	305 53 10	55	19·06	−19 55	305 33 15			
179	305 47 55	55	13·90	−14 32	305 33 23			
180	305 18 0	55	14·84	+15 31	305 33 31			
181	305 22 0	55	10·92	+11 25	305 33 25	305 33 23		
182	32 56 10	55	16·92	−17 42	32 38 28			
183	32 55 5	55	15·70	−16 25	32 38 40			
184	32 51 15	55	12·23	−12 47	32 38 28			
185	32 35 2	55	3·42	+ 3 35	32 38 37			
186	32 25 15	55	12·87	+13 27	32 38 42	32 38 35	43 32 36	2529·2

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
246*	305 20 0	65	0·55	+ 0 34	305 20 34			
247	305 25 0	65	4·39	− 4 32	305 20 28	305 20 31		
248	32 45 0	65	8·22	− 8 29	32 36 31			
249	32 40 0	65	3·27	− 3 23	32 36 37	32 36 34	43 38 2	2533·4
246*	305 20 0	65	0·35	− 0 22	305 19 38			
247	305 25 0	65	5·31	− 5 29	305 19 29	305 19 34		
248	32 45 0	65	7·20	− 7 26	32 37 34			
249	32 40 0	65	2·32	− 2 24	32 37 36	32 37 35	43 39 0	2534·2
246*	305 20 0	65	3·41	− 3 31	305 16 29			
247	305 25 0	65	8·27	− 8 33	305 16 27	305 16 28		
248	32 45 0	65	4·24	− 4 23	32 40 37			
249	32 40 0	65	0·65	+ 0 40	32 40 40	32 40 38	43 42 5	2536·6
178	305 53 10	55	28·22	−29 30	305 23 40			
179	305 47 55	55	23·04	−24 5	305 23 50			
180	305 18 0	55	5·71	+ 5 58	305 23 58			
181	305 22 0	55	1·74	+ 1 52	305 23 52	305 23 50		
182	32 56 10	55	7·90	− 8 15	32 47 55			
183	32 55 5	55	6·67	− 6 58	32 48 7			
184	32 51 15	55	3·20	− 3 21	32 47 54			
185	32 35 2	55	12·36	+12 55	32 47 57			
186	32 25 15	55	21·79	+22 47	32 48 2	32 47 59	43 42 5	2536·6
178	305 53 10	55	30·92	−32 19	305 20 51			
179	305 47 55	55	25·71	−26 53	305 21 2			
180	305 18 0	55	3·11	+ 3 15	305 21 15			
181	305 22 0	55	0·91	− 0 57	305 21 3	305 21 3		
182	32 56 10	55	5·40	− 5 39	32 50 31			
183	32 55 5	55	4·13	− 4 19	32 50 46			
184	32 51 15	55	0·76	− 0 48	32 50 27			
185	32 35 2	55	14·95	+15 38	32 50 40			
186	32 25 15	55	24·30	+25 24	32 50 39	32 50 37	43 44 47	2538·6
187	33 10 10	62	18·64	−19 19	32 50 51			
188	33 20 15	62	28·24	−29 16	32 50 59	32 50 55		
189	305 3 0	62	17·86	+18 31	305 21 31			
190	304 52 40	62	27·59	+28 36	305 21 16	305 21 23	43 44 46	2538·6
243	33 25 0	65	40·47	−41 48	32 43 12			
244	33 15 0	65	30·78	−31 47	32 43 13			
248	32 45 0	65	1·61	− 1 40	32 43 20			
249	32 40 0	65	3·27	+ 3 23	32 43 23	32 43 17		
245	304 50 0	65	23·15	+23 55	305 13 55			
246	304 45 0	65	27·85	+28 46	305 13 46			
246*	305 20 0	65	6·01	− 6 12	305 13 48			
247	305 25 0	65	11·01	−11 22	305 13 38	305 13 47	43 44 45	2538·6
242	33 30 0	65	32·13	−33 11	32 56 49			
243	33 25 0	65	27·25	−28 9	32 56 51			
244	33 15 0	65	17·63	−18 13	32 56 47	32 56 49		
245	304 50 0	65	9·83	+10 9	305 0 9			
246	304 45 0	65	14·56	+15 2	305 0 2	305 0 6	43 58 21	2549·1
242	33 30 0	65	31·41	−32 26	32 57 34			
243	33 25 0	65	26·58	−27 27	32 57 33			
244	33 15 0	65	16·87	−17 26	32 57 34	32 57 34		
245	304 50 0	65	8·99	+ 9 17	304 59 17			
246	304 45 0	65	13·77	+14 13	304 59 13	304 59 15	43 59 10	2549·7

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
242	33 30 0	65	30·64	−31 39	32 58 21			
243	33 25 0	65	25·75	−26 36	32 58 24			
244	33 15 0	65	16·12	−16 39	32 58 21	32 58 22		
245	304 50 0	65	8·19	+ 8 28	304 58 28			
246	304 45 0	65	12·89	+13 19	304 58 19	304 58 23	43 59 59	2550·3
242	33 30 0	65	15·64	−16 9	33 13 51			
243	33 25 0	65	10·74	−11 6	33 13 54			
244	33 15 0	65	1·13	− 1 10	33 13 50	33 13 52		
245	304 50 0	65	6·97	− 7 12	304 42 48			
246	304 45 0	65	2·27	− 2 21	304 42 39	304 42 43	44 15 34	2562·3
188	33 20 15	62	1·31	+ 1 21	33 21 36	33 21 36		
189	305 3 0	62	11·86	−12 18	304 50 42			
190	304 52 40	62	2·25	− 2 20	304 50 20	304 50 31	44 15 33	2562·3
242	33 30 0	65	14·50	−14 59	33 15 1			
243	33 25 0	65	9·57	− 9 53	33 15 7			
244	33 15 0	65	0·10	+ 0 6	33 15 6	33 15 5		
245	304 50 0	65	7·96	− 8 13	304 41 47			
246	304 45 0	65	3·45	− 3 34	304 41 26	304 41 36	44 16 44	2563·2
193	303 19 55	57	57·80	+60 16	304 20 11			
194	34 53 15	57	58·93	−61 27	33 51 48		44 45 48	(2585·3)
195	34 43 5	54	49·10	−51 23	33 51 42			
196	303 30 0	54	47·72	+49 57	304 9 57		44 45 52	2585·4
242	33 20 0	65	13·75	+14 12	33 44 12			
243	33 25 0	65	18·57	+19 11	33 44 11			
244	33 15 0	65	28·30	+29 14	33 44 14	33 44 12		
245	304 50 0	65	36·59	−37 47	304 12 13			
246	304 45 0	65	32·00	−33 3	304 11 57	304 12 5	44 46 4	(2585·5)
96	303 19 57	65	45·14	+46 37	304 6 34			
97	303 19 57	65	44·91	+46 26	304 6 23	304 6 29		
98	34 50 0	65	38·13	−39 23	34 10 37			
99	34 50 0	65	37·99	−39 14	34 10 46	34 10 41	45 2 6	2597·6
96	303 19 57	65	43·80	+45 14	304 5 11			
97	303 19 57	65	43·63	+45 4	304 5 1	304 5 6		
98	34 50 0	65	36·71	−37 55	34 12 5			
99	34 50 0	65	36·49	−37 41	34 12 19	34 12 12	45 3 33	(2598·7)
195	34 43 5	54	32·03	−33 32	34 9 33			
196	303 30 0	54	30·34	+31 45	304 1 45		45 3 54	(2599·0)
193	303 19 55	57	40·38	+42 2	304 1 58			2598·8
194	34 53 15	57	41·75	−43 32	34 9 43		45 3 52	(2599·0)
195	34 43 5	54	22·35	−23 24	34 19 41			
196	303 30 0	54	20·59	+21 33	303 51 33		45 14 4	(2606·6)
193	303 19 55	57	30·45	+31 45	303 51 40			2606·7
194	34 53 15	57	31·77	−33 8	34 20 7		45 14 13	(2606·8)
193	303 19 55	57	24·28	+25 19	303 45 14			
194	34 53 15	57	25·84	−26 57	34 26 18		45 20 32	(2611·5)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
195	34 43 5	54	16·24	−17 0	34 26 5			
196	303 30 0	54	14·57	+15 15	303 45 15		45 20 25	2611·4
96	303 19 57	65	27·72	+28 38	303 48 35			
97	303 19 57	65	27·54	+28 27	303 48 24	303 48 30		
98	34 50 0	65	20·89	−21 34	34 28 26			
99	34 50 0	65	20·75	−21 26	34 28 34	34 28 30	45 20 0	(2611·1)
96	303 19 57	65	25·14	+25 58	303 45 55			
97	303 19 57	65	24·93	+25 45	303 45 42	303 45 49		
98	34 50 0	65	18·34	−18 57	34 31 3			
99	34 50 0	65	18·33	−18 56	34 31 4	34 31 3	45 22 37	2613·1
96	303 19 57	65	20·18	+20 50	303 40 47			
97	303 19 57	65	20·05	+20 42	303 40 39	303 40 43		
98	34 50 0	65	13·41	−13 51	34 36 9			
99	34 50 0	65	13·28	−13 43	34 36 17	34 36 13	45 27 45	(2616·9)
195	34 43 5	54	8·94	− 9 21	34 33 44			
196	303 30 0	54	7·18	+ 7 31	303 37 31		45 28 6	2617·2
193	303 19 55	57	16·92	+17 39	303 37 33			
194	34 53 15	57	18·54	−19 20	34 33 55		45 28 11	2617·2
193	303 19 55	57	6·58	+ 6 52	303 26 47			
194	34 53 15	57	8·29	− 8 39	34 44 36		45 38 55	(2625·3)
195	34 43 5	54	1·18	+ 1 14	34 44 19			
196	303 30 0	54	3·14	− 3 17	303 26 43		45 38 48	2625·2
96	303 19 57	65	9·76	+10 5	303 30 2			
97	303 19 57	65	9·45	+ 9 46	303 29 43	303 29 53		
98	34 50 0	65	2·96	− 3 4	34 46 56			
99	34 50 0	65	2·84	− 2 55	34 47 5	34 47 0	45 38 33	(2625·0)
237	34 30 0	73	7·12	+ 7 17	34 37 17			
238	34 25 0	73	11·88	+12 9	34 37 9	34 37 11		
239	303 0 0	70	18·88	+19 19	303 19 19	303 19 18	45 38 56	(2625·3)
240	303 15 0	70	4·18	+ 4 17	303 19 17			
241	34 45 0	70	7·68	− 7 53	34 37 7			
96	303 19 57	65	6·18	+ 6 23	303 26 20			
97	303 19 57	65	5·91	+ 6 6	303 26 3	303 26 12		
98	34 50 0	65	0·52	+ 0 32	34 50 32			
99	34 50 0	65	0·63	+ 0 39	34 50 39	34 50 35	45 42 12	(2627·7)
193	303 19 55	57	3·12	+ 3 20	303 23 15			
194	34 53 15	57	4·94	− 5 9	34 48 6		45 42 25	2627·9
237	34 30 0	73	10·63	+10 53	34 40 53			
238	34 25 0	73	15·41	+15 46	34 40 46	34 40 47		
239	303 0 0	70	15·44	+15 48	303 15 48	303 15 45	45 42 31	2627·9
240	303 15 0	70	0·66	+ 0 41	303 15 41			
241	34 45 0	70	4·16	− 4 16	34 40 44			

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
195	34 43 5	54	4·62	+ 4 51	34 47 56			
196	303 30 0	54	6·53	− 6 50	303 23 10		45 42 23	2627·9
96	303 19 57	65	2·49	+ 2 34	303 22 31			
97	303 19 57	65	2·23	+ 2 18	303 22 15	303 22 23		
98	34 50 0	65	4·34	+ 4 29	34 54 29			
99	34 50 0	65	4·45	+ 4 36	34 54 36	34 54 33	45 46 5	(2630·6)
193	303 19 55	57	0·61	− 0 38	303 19 17			
194	34 53 15	57	1·41	− 1 28	34 51 47		45 46 15	2630·7
195	34 43 5	54	8·15	+ 8 32	34 51 37			
196	303 30 0	54	10·07	−10 32	303 19 28		45 46 5	(2630·6)
237	34 30 0	73	14·27	+14 36	34 44 36			
238	34 25 0	73	18·99	+19 26	34 44 26	34 44 29		
239	303 0 0	70	11·58	+11 51	303 11 51	303 11 55	45 46 17	(2630·8)
240	303 15 0	70	2·93	− 3 1	303 11 59			
241	34 45 0	70	0·59	− 0 36	34 44 24			
195	34 43 5	54	51·32	+53 36	35 36 41			
196	303 30 0	54	53·71	−56 13	302 33 47		46 31 27	(2664·2)
232	302 30 0	76	2·77	− 2 49	302 27 11			
234	302 35 0	76	7·66	− 7 48	302 27 12	302 27 11		
235	35 30 0	76	0·16	− 0 10	35 29 50		46 31 20	2664·1
323	302 25 0	76	2·84	+ 2 54	302 27 54			
324	35 30 0	76	0·00	0 0	35 30 0		46 31 3	(2663·9)
195	34 43 5	54	53·96	+56 28	35 39 33			
196	303 30 0	54	56·38	−59 0	302 31 0		46 34 17	(2666·3)
323	302 25 0	76	0·23	+ 0 14	302 25 14			
324	35 30 0	76	2·57	+ 2 37	35 32 37		46 33 42	(2665·8)
232	302 30 0	76	5·41	− 5 31	302 24 29			
234	302 35 0	76	10·32	−10 31	302 24 29	302 24 29		
235	35 30 0	76	2·51	+ 2 34	35 32 34		46 34 3	2666·1
225	37 0 0	79	61·41	−62 22	35 57 38			
228	36 30 0	79	32·14	−32 39	35 57 21	35 57 29		
226	301 5 0	79	53·53	+54 22	301 59 22			
227	301 35 0	79	24·15	+24 32	301 59 32	301 59 27	46 59 1	(2684·4)
232	302 30 0	76	29·89	−30 28	301 59 32			
234	302 35 0	76	34·72	−35 23	301 59 37	301 59 34		2684·2
235	35 30 0	76	26·71	+27 14	35 57 14			
236	35 35 0	76	21·87	+22 18	35 57 18	35 57 16	46 58 51	(2684·3)
323	302 25 0	76	24·21	−24 41	302 0 19			
324	35 30 0	76	26·82	+27 21	35 57 21		46 58 31	(2684·0)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
232	302 30 0	76	40·61	−41 24	301 48 36			
234	302 35 0	76	45·34	−46 12	301 48 48	301 48 42		
235	35 30 0	76	37·31	+38 2	36 8 2			
236	35 35 0	76	32·46	+33 5	36 8 5	36 8 4	47 9 41	2692·1
323	302 25 0	76	34·83	−35 30	301 49 30			
324	35 30 0	76	37·46	+38 11	36 8 11		47 9 21	(2691·9)
225	37 0 0	79	50·81	−51 36	36 8 24			
228	36 30 0	79	21·49	−21 50	36 8 10	36 8 17		2692·1
226	301 5 0	79	42·77	+43 26	301 48 26			
227	301 35 0	79	13·40	+13 37	301 48 37	301 48 32	47 9 52	(2692·2)
225	37 0 0	79	35·43	−35 59	36 24 1			
228	36 30 0	79	6·09	− 6 11	36 23 49	36 23 55		
226	301 5 0	79	27·19	+27 37	301 32 37			
227	301 35 0	79	2·23	− 2 16	301 32 44	301 32 41	47 25 37	2703·6
197	300 59 55	65	25·63	+26 28	301 26 23			
198	301 10 0	65	15·74	+16 16	301 26 16	301 26 20		
200	37 3 0	65	16·83	−17 23	36 45 37			
201	37 12 55	65	26·64	−27 31	36 45 24	36 45 30	47 39 35	(2713·7)
225	37 0 0	79	21·26	−21 36	36 38 24			
228	36 30 0	79	8·10	+ 8 14	36 38 14	36 38 19		2713·8
226	301 5 0	79	12·95	+13 9	301 18 9			
227	301 35 0	79	16·48	−16 21	301 18 39	301 18 24	47 39 58	(2714·0)
225	37 0 0	79	3·43	− 3 29	36 56 31			
228	36 30 0	79	26·04	+26 27	36 56 27	36 56 29		
226	301 5 0	79	5·05	− 5 8	300 59 52			
227	301 35 0	79	34·46	−35 0	301 0 0	300 59 56	47 58 16	(2727·1)
197	300 59 55	65	7·78	+ 8 2	301 7 57			
198	301 10 0	65	2·14	− 2 13	301 7 57	301 7 57		2727 0
200	37 3 0	65	0·88	+ 0 55	37 3 55			
201	37 12 55	65	8·75	− 9 2	37 3 53	37 3 54	47 57 58	(2726·9)
197	300 59 55	65	8·68	− 8 58	300 50 57			
198	301 10 0	65	18·58	−19 11	300 50 49	300 50 55		
200	37 3 0	65	17·27	+17 50	37 20 50			
201	37 12 55	65	7·59	+ 7 50	37 20 45	37 20 48	48 14 57	(2739·0)
229	37 30 0	86	16·07	−16 11	37 13 49			2739·1
230	300 35 0	86	7·97	+ 8 2	300 43 2			
231	300 30 0	86	12·87	+12 58	300 42 58	300 43 0	48 15 24	(2739·3)
229	37 30 0	86	10·99	−11 4	37 18 56			
230	300 35 0	86	2·88	+ 2 54	300 37 54			
231	300 30 0	86	7·81	+ 7 52	300 37 52	300 37 53	48 20 31	(2743·0)
197	300 59 55	65	13·79	−14 15	300 45 40			
198	301 10 0	65	23·62	−24 24	300 45 36	300 45 38		2742·8
200	37 3 0	65	22·23	+22 57	37 25 57			
201	37 12 55	65	12·47	+12 53	37 25 48	37 25 53	48 20 8	(2742·7)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
197	300 59 55	65	18·35	−18 57	300 40 58			
198	301 10 0	65	28·21	−29 18	300 40 52	300 40 55		(2746·0)
200	37 3 0	65	26·68	+27 33	37 30 33			
201	37 12 55	65	17·04	+17 36	37 30 31	37 30 32	48 24 49	2746·1
229	37 30 0	86	6·46	− 6 31	37 23 29			
230	300 35 0	86	1·71	− 1 43	300 33 17			
231	300 30 0	86	3·27	+ 3 18	300 33 18	300 33 17	48 25 6	(2746·2)
229	37 30 0	86	5·78	− 5 49	37 24 11			
230	300 35 0	86	2·38	− 2 24	300 32 36			
231	300 30 0	86	2·56	+ 2 35	300 32 35	300 32 36	48 25 47	2746·7
197	300 59 55	65	18·99	−19 37	300 40 18			
198	301 10 0	65	28·85	−29 48	300 40 12	300 40 15		
200	37 3 0	65	27·38	+28 17	37 31 17			
201	37 12 55	65	17·69	+18 39	37 31 34	37 31 26	48 25 36	(2746·6)
197	300 59 55	65	22·23	−22 58	300 36 57			
198	301 10 0	65	32·12	−33 10	300 36 50	300 36 53		
200	37 3 0	65	30·57	+31 34	37 34 34			
201	37 12 55	65	20·97	+22 7	37 35 2	37 34 48	48 28 58	(2749·1)
229	37 30 0	86	2·51	− 2 32	37 27 28			
230	300 35 0	86	5·65	− 5 41	300 29 19			
231	300 30 0	86	0·74	− 0 45	300 29 15	300 29 17	48 29 6	2749·0
128	301 4 55	67	27·80	−28 39	300 36 16			
129	301 4 55	67	27·61	−28 27	300 36 28			
131	300 54 55	67	18·32	−18 53	300 36 2	300 36 15		
125	37 20 5	67	15·66	+16 18	37 36 13			
124	37 30 5	70	6·09	+ 6 15	37 36 20	37 36 17	48 30 1	2749·7
229	37 30 0	86	2·96	+ 2 59	37 32 59			
230	300 35 0	86	11·25	−11 20	300 23 40			
231	300 30 0	86	6·27	− 6 19	300 23 41	300 23 40	48 34 39	2753·0
229	37 30 0	86	6·42	+ 6 28	37 36 28			
230	300 35 0	86	14·71	−14 49	300 20 11			
231	300 30 0	86	9·74	− 9 49	300 20 11	300 20 11	48 38 9	2755·5
197	300 59 55	65	31·13	−32 9	300 27 44			
198	301 10 0	65	41·00	−42 21	300 27 39	300 27 41		
200	37 3 0	65	39·44	+40 44	37 43 44			
201	37 12 55	65	29·76	+31 23	37 44 18	37 44 1	48 38 10	2755·5
197	300 59 55	65	47·45	−49 0	300 10 55			
198	301 10 0	65	57·22	−59 6	300 10 54	300 10 54		
200	37 3 0	65	55·57	+57 23	38 0 23			
201	37 12 55	65	45·88	+48 23	38 1 18	38 0 51	48 54 58	(2767·3)
220	299 35 0	79	27·90	+28 20	300 3 20			
221	299 35 0	79	27·82	+28 15	300 3 15	300 3 18		
222	38 30 0	79	36·45	−37 1	37 52 59			
218	38 30 0	79	36·32	−36 53	37 53 7			
219	38 25 0	79	31·56	−32 3	37 52 57	37 53 2	48 54 52	2767·2
286	38 20 0	84	26·85	−27 7	37 52 53			
287	299 40 0	84	23·15	+23 23	300 3 23		48 54 45	(2767·1)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
286	38 20 0	84	10·20	−10 18	38 9 42			
287	299 40 0	84	6·27	+ 6 20	299 46 20		49 11 41	2779·0
220	299 35 0	79	11·26	+11 27	299 46 27			
221	299 35 0	79	11·16	+11 20	299 46 20	299 46 24		
222	38 30 0	79	19·96	−20 16	38 9 44			
218	38 30 0	79	19·78	−20 5	38 9 55			
219	38 25 0	79	14·98	−15 13	38 9 47	38 9 51	49 11 43	2779·0
220	299 35 0	79	5·06	+ 5 8	299 40 8			
221	299 35 0	79	4·95	+ 5 2	299 40 2	299 40 5		
222	38 30 0	79	13·80	−14 1	38 15 59			
218	38 30 0	79	13·62	−13 51	38 16 9			
219	38 25 0	79	8·84	− 8 59	38 16 1	38 16 3	49 17 59	2783·4
286	38 20 0	84	3·97	− 4 1	38 15 59			
287	299 40 0	84	0·05	+ 0 3	299 40 3		49 17 58	2783·4
321	39 0 0	86	20·58	−20 43	38 39 17			
322	298 55 0	86	23·65	+23 49	299 18 49		49 40 14	2798·8
321	39 0 0	86	0·52	− 0 31	38 59 29			
322	298 55 0	86	3·26	+ 3 17	298 58 17		50 0 36	2812·9
321	39 0 0	86	25·93	+26 7	39 26 7			
322	298 55 0	86	23·26	−23 26	298 31 34		50 27 17	2831·1
281	298 25 0	87	5·95	+ 5 59	298 30 59			
284	298 25 0	87	5·81	+ 5 51	298 30 51	298 30 55		
282	39 35 0	87	9·27	− 9 20	39 25 40			
283	39 35 0	87	9·74	− 9 48	39 25 12			
285	39 35 0	87	9·60	− 9 40	39 25 20	39 25 24	50 27 14	(2831·0)
281	298 25 0	87	0·13	− 0 8	298 24 52			
284	298 25 0	87	0·36	− 0 22	298 24 38	298 24 45		
282	39 35 0	87	3·20	− 3 13	39 31 47			
283	39 35 0	87	2·71	− 2 44	39 32 16			
285	39 35 0	87	3·58	− 3 36	39 31 24	39 31 49	50 33 32	2835·3
281	298 25 0	87	7·47	− 7 31	298 17 29			
284	298 25 0	87	7·59	− 7 38	298 17 22	298 17 25		
282	39 35 0	87	3·99	+ 4 1	39 39 1			
283	39 35 0	87	4·54	+ 4 34	39 39 34			
285	39 35 0	87	3·58	+ 3 36	39 38 36	39 39 5	50 40 50	2840·3
288	297 25 0	88	25·62	+25 45	297 50 45			
289	40 35 0	88	30·28	−30 26	40 4 26		51 6 51	(2857·8)
318	297 20 0	88	31·35	+31 30	297 51 30			2857·9
319	297 20 0	88	31·40	+31 33	297 51 33	297 51 32		
320	40 30 0	88	23·73	−23 51	40 6 9		51 7 18	(2858·1)
278	40 35 0	88	29·57	−29 43	40 5 17			
279	297 25 0	88	26·13	+26 16	297 51 16			
280	297 25 0	88	26·34	+26 28	297 51 28	297 51 22	51 6 57	(2857·8)

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
278	40 35 0	88	8·62	− 8 40	40 26 20			
280	297 25 0	88	5·29	+ 5 19	297 30 19		51 28 0	(2871·9)
288	297 25 0	88	4·54	+ 4 34	297 29 34			
289	40 35 0	88	9·45	− 9 30	40 25 30		51 27 58	(2871·9)
318	297 20 0	88	10·37	+10 25	297 30 25			2872·0
319	297 20 0	88	10·34	+10 24	297 30 24	297 30 25		
320	40 30 0	88	2·77	− 2 47	40 27 13		51 28 24	(2872·2)
269	40 50 0	91	21·93	−21 58	40 28 2			
270	40 55 0	91	27·00	−27 2	40 27 58	40 28 0		
271	297 10 0	91	18·96	+18 59	297 28 59			
272	297 5 0	91	23·94	+23 59	297 28 59		51 29 30	(2872·9)
288	297 25 0	88	3·02	+ 3 2	297 28 2			
289	40 35 0	88	7·86	− 7 54	40 27 6		51 29 32	(2872·9)
317	297 25 0	88	3·94	+ 3 58	297 28 58			2873·0
318	297 20 0	88	8·93	+ 8 59	297 28 59			
319	297 20 0	88	8·86	+ 8 54	297 28 54	297 28 57		
320	40 30 0	88	1·36	− 1 22	40 28 38		51 29 51	(2873·1)
278	40 35 0	88	7·12	− 7 9	40 27 51			
279	297 25 0	88	3·47	+ 3 29	297 28 29			
280	297 25 0	88	3·78	+ 3 48	297 28 48	297 28 39	51 29 36	2873·0
278	40 35 0	88	3·82	+ 3 50	40 38 50			
280	297 25 0	88	7·58	− 7 37	297 17 23		51 40 48	2880·4
269	40 50 0	91	10·94	−10 58	40 39 2			
270	40 55 0	91	15·99	−16 1	40 38 59	40 39 0		
271	297 10 0	91	7·66	+ 7 40	297 17 40			
272	297 5 0	91	12·56	+12 35	297 17 35	297 17 38	51 40 41	(2880·3)
288	297 25 0	88	8·12	− 8 10	297 16 50			
289	40 35 0	88	3·18	+ 3 12	40 38 12		51 40 41	(2880·3)
317	297 25 0	88	7·28	− 7 19	297 17 41			
318	297 20 0	88	2·56	− 2 34	297 17 26			
319	297 20 0	88	2·46	− 2 28	297 17 32	297 17 33		
320	40 30 0	88	9·75	+ 9 48	40 39 48		51 41 7	(2880·6)
269	40 50 0	91	6·50	− 6 31	40 43 29			
270	40 55 0	91	11·55	−11 34	40 43 26	40 43 27		
271	297 10 0	91	3·21	+ 3 13	297 13 13			
273	297 5 0	91	8·14	+ 8 12	297 13 12	297 13 12	51 45 7	2883·3
278	40 35 0	88	8·17	+ 8 13	40 43 13			
279	297 25 0	88	11·92	−11 59	297 13 1			
280	297 25 0	88	11·84	−11 54	297 13 6	297 13 3	51 45 5	2883·3
288	297 25 0	88	12·53	−12 36	297 12 24			
289	40 35 0	88	7·52	+ 7 34	40 42 34		51 45 5	2883·3

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
317	297 25 0	88	11·59	−11 39	297 13 21			
318	297 20 0	88	6·95	− 6 59	297 13 1			
319	297 20 0	88	6·77	− 6 48	297 13 12	297 13 11		
320	40 30 0	88	14·13	+14 12	40 44 12	..	51 45 31	(2883·5)
275	296 10 0	93	2·48	− 2 29	296 7 32			
276	41 50 0	93	0·91	− 0 55	41 49 5			
277	41 55 0	93	6·00	− 6 1	41 48 59	41 49 2	52 50 45	(2926·1)
267	296 10 0	93	2·85	− 2 51	296 7 9			
268	41 50 0	93	1·20	− 1 12	41 48 48	..	52 50 50	2926·0
310	41 55 0	93	10·19	+10 11	42 5 11			
311	41 50 0	93	15·00	+14 59	42 4 59	42 5 5		
312	296 0 0	93	8·16	− 8 9	295 51 51	..	53 6 37	2928·3
267	296 10 0	93	30·58	−30 33	295 39 27			
268	41 50 0	93	26·50	+26 29	42 16 29	..	53 18 31	(2943·9)
275	296 10 0	93	30·48	−30 27	295 39 33			
276	41 50 0	93	26·78	+26 45	42 16 45			
277	41 55 0	93	21·73	+21 43	42 16 43	42 16 44	53 18 36	2944·0
310	41 55 0	93	21·95	+21 56	42 16 56			
311	41 50 0	93	26·75	+26 44	42 16 44	42 16 50		
312	296 0 0	93	20·04	−20 1	295 39 59			
315	296 0 0	93	19·97	−19 57	295 40 3	295 40 1	53 18 25	(2943·9)
275	296 10 0	93	35·50	−35 28	295 34 32			
276	41 50 0	93	31·94	+31 55	42 21 55			U
277	41 55 0	93	26·89	+26 52	42 21 52	42 21 54	53 23 41	2947·3

As in the highest region we have used the lines in the spectrum of the spark between copper electrodes as lines of reference, we add here the measurements and calculated values for these lines, and for the strong magnesium lines which we have sometimes used in interpolating.

Copper Lines.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
327	312 55 0	24	27·88	+30 17	313 25 17			
330	313 5 0	24	18·19	+19 46	313 24 46			
331	313 5 0	24	18·81	+20 26	313 25 26	313 25 10		
328	25 0 0	24	23·96	−26 2	24 33 58			
329	24 45 0	24	10·30	−11 11	24 33 49	24 33 53	35 34 21	2135·7
327	312 55 0	24	13·87	+15 4	313 10 4			
330	313 5 0	24	4·17	+ 4 32	313 9 32			
331	313 5 0	24	4·73	+ 5 8	313 10 8	313 9 55		
328	25 0 0	24	10·15	−11 2	24 48 58			
329	24 45 0	24	3·53	+ 3 50	24 48 50	24 48 54	35 49 30	2148·9

Copper Lines—(continued).

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
297	25 50 0	31	24·22	−26 5	25 23 55			
298	312 10 0	31	23·66	+25 29	312 35 29		36 24 13	2178·8
297	25 50 0	31	13·18	−14 11	25 35 49			
298	312 10 0	31	12·24	+13 11	312 23 11		36 36 19	2189·2
325	26 0 0	31	22·94	−24 42	25 35 18			
326	311 55 0	31	25·83	+27 49	312 22 49		36 36 14	2189·2
325	26 0 0	31	20·02	−21 33	25 38 27			
326	311 55 0	31	22·98	+24 45	312 19 45		36 39 21	2191·8
297	25 50 0	31	10·32	−11 7	25 38 53			
298	312 10 0	31	9·37	+10 5	312 20 5		36 39 24	(2191·9)
297	25 50 0	31	2·37	− 2 33	25 47 27			
298	312 10 0	31	1·46	+ 1 34	312 11 34		36 47 56	2199·2
325	26 0 0	31	0·65	− 0 42	25 59 18			
326	311 55 0	31	3·19	+ 3 26	311 58 26		37 0 26	(2209·9)
291	26 25 0	37	23·62	−25 15	25 59 45			
293	26 35 0	37	33·52	−35 55	25 59 5			
296	26 25 0	34	23·27	−24 55	26 0 5			
297	25 50 0	31	9·08	+ 9 47	25 59 47	25 59 40		
298	312 10 0	31	10·19	−10 58	311 59 2			
299	311 10 0	39	46·93	+50 2	312 0 2			2209·7
294	311 25 0	37	31·70	+33 53	311 58 53			
295	311 35 0	34	22·73	+24 23	311 59 23	311 59 20	37 0 10	(2209·6)
291	26 25 0	37	15·26	−16 19	26 8 41			
293	26 35 0	37	24·69	−26 27	26 8 33			
296	26 25 0	34	14·80	−15 53	26 9 7			
297	25 50 0	31	17·55	+18 54	26 8 54			
300	26 50 0	39	39·24	−41 50	26 8 10	26 8 41		
294	311 25 0	37	22·94	+24 31	311 49 31			
295	311 35 0	34	14·04	+15 4	311 50 4			2217·5
298	312 10 0	31	18·77	−20 13	311 49 47			
299	311 10 0	39	37·91	+40 25	311 50 25	311 49 57	37 9 22	
325	26 0 0	31	7·68	+ 8 16	26 8 16			
326	311 55 0	31	5·40	− 5 49	311 49 11		37 9 33	(2217·6)
291	26 25 0	37	3·49	− 3 44	26 21 16			
293	26 35 0	37	12·99	−13 55	26 21 5			
296	26 25 0	34	3·05	− 3 16	26 21 44			
300	26 50 0	39	27·23	−29 2	26 20 58	26 21 16		
294	311 25 0	37	10·95	+11 42	311 36 42			
295	311 35 0	34	1·87	+ 2 0	311 37 0			
299	311 10 0	39	25·85	+27 33	311 37 33	311 37 5	37 22 5	2228·3
293	26 35 0	37	11·58	−12 24	26 22 36			
296	26 25 0	34	1·65	− 1 46	26 23 14	26 22 55		
294	311 25 0	37	9·51	+10 10	311 35 10			
295	311 35 0	34	0·51	+ 0 32	311 35 32			
299	311 10 0	39	24·52	+26 8	311 36 8	311 35 37	37 23 39	2229·6

Copper Lines—(continued).

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	′ ″		hundredths of an inch.	′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
291	26 25 0	37	11·59	+12 23	26 37 23			
292	26 30 0	38	7·30	+ 7 47	26 37 47			
293	26 35 0	37	2·15	+ 2 18	26 37 18			
296	26 25 0	34	12 00	+12 52	26 37 52			
300	26 50 0	39	11·52	− 12 17	26 37 43	26 37 37		
294	311 25 0	37	4·54	− 4 51	311 20 9			
295	311 35 0	34	13·28	−14 15	311 20 45			
299	311 10 0	39	10·15	+10 49	311 20 49	311 20 34	37 33 31	2242·2
332	27 0 0	39	20·54	−21 54	26 38 6			
333	26 55 0	39	15·96	−17 1	26 37 59	26 38 2		
334	310 55 0	39	24·32	+25 56	311 20 56			
335	311 0 0	39	19·70	+20 49	311 20 49	311 20 53	37 38 34	2242·2
332	27 0 0	39	15·77	−16 49	26 43 11			
333	26 55 0	39	11·03	−11 46	26 43 14	26 43 12		
334	310 55 0	39	19·47	+20 46	311 15 46			
335	311 0 0	39	14·61	+15 27	311 15 27	311 15 37	37 43 47	2246·6
291	26 25 0	37	16·48	+17 37	26 42 37			
292	26 30 0	38	12·16	+12 59	26 42 59			
293	26 35 0	37	7·03	+ 7 32	26 42 32			
296	26 25 0	34	16·80	+18 1	26 43 1			
300	26 50 0	39	6·62	− 7 3	26 42 57	26 42 49		
294	311 25 0	37	9·45	−10 6	311 14 54			
295	311 35 0	34	18·20	−19 31	311 15 29			
299	311 10 0	39	5·31	+ 5 40	311 15 40	311 15 21	37 43 44	2246·6
332	27 0 0	39	2·98	+ 3 10	27 3 10			
333	26 55 0	39	7·80	+ 8 19	27 3 19	27 3 15		
335	311 0 0	39	4·27	− 4 31	310 55 29		38 3 53	2263·6
332	27 0 0	39	16·90	+18 1	27 18 1			
333	26 55 0	39	21·60	+23 2	27 18 2			
334	310 55 0	39	13·52	−14 25	310 40 35			
335	311 0 0	39	18·18	−19 13	310 40 47			
336	310 30 0	46	10·33	+10 55	310 40 55			
337	310 25 0	46	15·12	+15 59	310 40 59	310 40 49		
338	27 30 0	46	11·24	−11 53	27 18 7			
340	27 35 0	46	16·00	−16 55	27 18 5			
339	27 25 0	46	6·71	− 7 6	27 17 54	27 18 2	38 18 37	2276·0
291	26 25 0	37	48·59	+51 56	27 16 56			
292	26 30 0	38	44·59	+47 36	27 17 36			
293	26 35 0	37	39·99	+42 51	27 17 51			
296	26 25 0	34	48·64	+52 11	27 17 11			
300	26 50 0	39	26·44	+28 11	27 18 11	27 17 38		
294	311 25 0	37	42·01	−44 54	310 40 6			
295	311 35 0	34	50·70	−54 23	310 40 37			
299	311 10 0	39	27·31	−29 7	310 40 53	310 40 32	38 18 33	(2275·9)
336	310 30 0	46	10·33	−10 55	310 19 5			
337	310 25 0	46	5·55	− 5 52	310 19 8	310 19 6		
338	27 30 0	46	9·30	+ 9 50	27 39 50			
340	27 35 0	46	4·40	+ 4 39	27 39 39			
339	27 25 0	46	13·76	+14 33	27 39 33	27 39 41	38 40 19	2294·1

MAGNESIUM LINES.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	° ′ ″		hundredths of an inch.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	wave-length.
129	301 4 55	67	68·67	−1 10 45	299 54 10			
128	301 4 55	67	68·85	−1 10 58	299 53 57			
131	300 54 55	67	59·32	−1 1 7	299 53 48	299 54 4		
134	300 4 55	75	10·67	−0 10 53	299 54 2			
135	300 4 55	75	10·39	−0 10 36	299 54 19			
139	300 0 3	72	5·66	−0 5 47	299 54 16			
140	300 0 3	72	5·95	−0 6 6	299 53 57			
137	38 10 0	75	8·75	+0 8 56	38 18 56			
138	38 15 0	72	3·42	+0 3 30	38 18 30			
125	37 20 5	67	56·82	+0 58 32	38 18 37			
124	37 30 5	70	47·33	+0 48 35	38 18 40	38 18 41	49 12 19	2779·4
137	38 10 0	75	30·88	+0 31 31	38 41 31			
138	38 15 0	72	25·68	+0 26 18	38 41 18	38 41 25		
139	300 0 3	72	27·86	−0 28 32	299 31 31			
140	300 0 3	72	28·02	−0 28 42	299 31 21	299 31 26	49 35 0	2795·2
306	299 15 0	86	8·75	+0 8 49	299 23 49	299 23 50		
307	38 45 0	86	10·89	−0 11 1	38 33 59			
308	38 30 0	85	3·84	+0 3 52	38 33 52	38 33 55		
309	299 30 0	85	6·10	−0 6 9	299 23 51		49 35 2	2795·2
137	38 10 0	75	41·09	+0 41 56	38 51 56			
138	38 15 0	72	35·83	+0 36 42	38 51 42	38 51 49		
139	300 0 3	72	37·82	−0 38 44	299 21 19			
140	300 0 3	72	38·21	−0 39 8	299 20 55	299 21 7	49 45 21	2802·4
306	299 15 0	86	1·57	−0 1 35	299 13 25			
307	38 45 0	86	0·59	−0 0 36	38 44 24			
308	38 30 0	85	14·16	+0 14 17	38 44 17	38 44 21		
309	299 30 0	85	16·48	−0 16 37	299 13 23	299 13 24	49 45 28	(2802·4)
303	40 0 0	85	2·97	−0 3 0	39 57 0			
304	298 0 0	85	0·34	+0 0 21	298 0 21			
305	298 5 0	85	4·48	−0 4 31	298 0 29	298 0 25	50 58 18	2852·0

Remarks on the foregoing tables.

It will be observed that when two or more independent determinations have been made the wave-lengths found are often identical, rarely differ by more than ·2 of a tenth-metre. This seems to make the probable error in most cases very small—smaller than we venture to think it really may be, for there are one or two sources of error which are quite sufficient to account for a variation of ·2 of a tenth-metre in the wave-length. First the sliding tubes of the telescope, for it has a draw tube as well as the usual rack and pinion arrangement for focussing, in order to allow for the great variations in the focal distance of the uncorrected quartz lenses, and such sliding tubes have always some play, so that in the operation of reversing the photographic plate by turning the sliding tube about its axis there might easily be a small displacement.

Indeed, the measurement of plates taken successively without movement of any part of the apparatus, except the photographic slide, showed that there was such a displacement of the axis, and that it might make an error of $\pm 10''$ in the measurement of the angle, or $\pm \cdot 13$ on an average in the value of the wave-length.

Another source of error is the want of sharp definition of some of the lines. Some of the lines are really diffuse, and in every case, as already observed, if the image is correctly focussed on the plate when the telescope is on one side of the collimator, it is always a little out of focus when the telescope is moved round to the other side. Hence there may easily be an error in measuring the distance between the lines which may easily amount to $\pm 8''$ of angular measure, or $\pm \cdot 1$ in the value of the wave-length.

Still we do not think the probable error exceeds $\pm \cdot 25$ of a tenth-metre.

Determination of the intermediate lines.

The wave-lengths of a sufficient number of lines of reference having been measured by the grating, the intermediate lines have been mapped by means of prisms. For this part of the work a calcite prism of 30°, cut so that one face is perpendicular to the axis of the crystal, was fixed to the end of the collimator, and a similar prism to the end of the telescope, while between them another calcite prism of 60°, cut so that the faces are equally inclined to the axis of the crystal, was maintained by a simple system of linkage at the position of minimum deviation, which is also that of single refraction. Photographs were taken at short intervals all down the scale of the spectrum of the arc and spark simultaneously. The image of the arc was focussed on the slit by the quartz lens already mentioned, and thrown just under the centre. At the same time the spark was made to pass horizontally close in front of the slit, without the interposition of a lens, but just above the centre. In this way two images were impressed on the plate overlapping one another in the middle. The distances between the lines was afterwards measured under the microscope, and the inverse squares of the wave-lengths of the intermediate lines deduced by the graphic method of interpolation between those of the lines of reference. A table of inverse squares was used for the reduction to simple wave-lengths.

The following table gives the results. In many cases there is much difference in the relative intensities of the same line in the arc and spark, and in some cases lines are visible in the photograph of the arc which are not in that of the spark, and *vice versâ*. Beyond the wave-length 2327 no spark lines seem to have made any impression on the plates, but the arc lines continue with, however, a sensible falling off in intensity up to the end of the region observed. For this region the copper lines of reference were used, as already explained, and for the highest part of it, above wave-length 2230, quartz prisms were substituted for those of calcite with advantage as regards the amount of light transmitted, but with some loss of dispersion and more of definition.

In the following table the second column gives the wave-length, and the lines marked with a "*c*" are probably carbon lines, the first gives approximately the relative intensities with which the lines are impressed on the photographic plates, 1 representing the strongest and 6 the weakest lines. It also indicates whether the line is an arc or a spark-line, *a* indicating arc-lines; *s*, spark-lines. Thus 3 *a* 1 *s* after a line indicates that its intensity in arc is 3, in spark, 1; 6 *a* indicates a line which is in arc only and of intensity 6; 2 *a s* indicates a line of intensity 2 in both arc and spark.

List of ultra-violet iron lines.

6 *a*	2167·4	4 *a*	2280 0	6 *a*	2341·2	2 *a s*	2384·2	2 *s*	2427·9
6 *a*	2171·7	6 *a*	2281·8	6 *s*	2341·6	6 *a* 5 *s*	2384·8	6 *a s*	2428·5
6 *a*	2173·4	6 *a*	2282·8	6 *s*	2341·8	6 *a*	2385·8	6 *s*	2428·7
6 *a*	2177·0	5 *a*	2283·0	1 *a s*	2343·1	4 *s*	2386·3	6 *a s*	2429·0
6 *a*	2178·0	5 *a*	2283·2	6 *a* 5 *s*	2343·6	6 *a* 4 *s*	2387·2	3 *a* 2 *s*	2429·7
6 *a*	2181·5	4 *a*	2283·6	4 *a* 3 *s*	2343·9	6 *s*	2388·0	6 *a s*	2430·5
6 *a*	2183·7	3 *a*	2284·0	4 *a*	2344·7	1 *a s*	2388·4	6 *a*	2430·7
6 *a*	2186·1	3 *a*	2287·1	3 *s*	2344·9	6 *s*	2389·2	6 *a* 2 *s*	2431·8
6 *a*	2186·8	3 *a*	2287·4	6 *a s*	2345·9	3 *a*	2389·9	2 *s*	2432·5
6 *a*	2191·3	6 *a*	2287·9	6 *s*	2346·4	5 *s*	2390·1	4 *s*	2433·2
5 *a*	2195·5	3 *a*	2288·8	1 *a s*	2347·8	6 *s*	2390·7	6 *a s*	2433·9
5 *a*	2199·3	5 *a*	2289·9	1 *a s*	2348·0	3 *a* 4 *s*	2391·3	6 *a* 3 *s*	2434·3
6 *a*	2200·0	4 *a*	2290·3	6 *s*	2349·0	6 *a s*	2392·4	5 *a* 3 *s*	2434·7
6 *a*	2200·2	6 *a*	2290·6	6 *a*	2349·5	6 *a*	2392·8	6 *a s*	2435·6
4 *a*	2207·5	4 *a*	2290·9	6 *a s*	2349·9	6 *a*	2394·1	6 *a s*	2436·0
4 *a*	2210·4	6 *a*	2291·4	6 *a* 2 *s*	2350·9	6 *s*	2394·7	5 *s*	2436·4
6 *a*	2211·4	3 *a*	2292·3	6 *a s*	2351·5	3 *a s*	2395·2	5 *s*	2436·9
4 *a*	2214·1	3 *a*	2293·6	6 *s*	2352·1	1 *a s*	2395·4	6 *s*	2437·3
3 *a*	2216·2	3 *a*	2294·2	5 *s*	2353·3	5 *s*	2396·5	4 *a*	2437·9
4 *a*	2225·2	3 *a*	2296·8	6 *a* 3 *s*	2354·1	6 *a*	2398·0	2 *s*	2439·0
3 *a*	2227·3	3 *a*	2297·6	3 *a s*	2354·6	6 *s*	2398·5	2 *a* 6 *s*	2439·4
3 *a*	2229·7	3 *a*	2298·0	5 *s*	2354·8	1 *a s*	2399·0	3 *a*	2439·8
6 *a*	2230·9	4 *a*	2298·6	6 *a* 5 *s*	2355·1	6 *a* 2 *s*	2400·0	3 *s*	2440·1
6 *a*	2240·2	3 *a*	2299·0	6 *a*	2355·6	6 *a s*	2401·0	6 *s*	2441·0
6 *a*	2242·2	6 *a*	2299·2	4 *s*	2356·7	6 *a*	2401·4	6 *a*	2441·5
6 *a*	2243·9	3 *a*	2300·0	1 *a s*	2358·7	6 *a* 5 *s*	2401·9	2 *a* 5 *s*	2442·3
5 *a*	2245·3	5 *a*	2300·4	6 *a s*	2359·2	6 *a* 5 *s*	2402·3	3 *a* 6 *s*	2443·7
4 *a*	2248·5	4 *a*	2301·0	2 *a* 1 *s*	2359·7	3 *a s*	2404·2	5 *a* 1 *s*	2444·3
4 *a*	2248·8	3 *a*	2301·4	2 *a* 1 *s*	2359·9	1 *a s*	2404·5	6 *a s*	2444·9
4 *a*	2250·5	3 *a*	2303·2	6 *a*	2360·3	6 *s*	2405·5	6 *a* 3 *s*	2445·4
6 *a*	2250·6	3 *a*	2303·4	6 *s*	2361·3	1 *a s*	2406·3	6 *s*	2445·9
6 *a*	2251·2	5 *a*	2304·4	4 *a* 3 *s*	2361·6	6 *s*	2406·6	6 *a* 3 *s*	2446·3
6 *a*	2251·6	5 *a*	2305·8	6 *s*	2362·9	6 *a*	2406·9	3 *s*	2447·1
4 *a*	2252·8	4 *a*	2306·0	3 *s*	2363·3	6 *a*	2407·3	3 *a s*	2447·5
4 *a*	2255·4	2 *a*	2308 6	3 *s*	2363·5	6 *a s*	2407·6	6 *a*	2448·1
4 *a*	2259·2	6 *a*	2309·3	2 *a* 1 *s*	2364·4	6 *s*	2408·4	6 *a*	2448·5
4 *a*	2259·8	6 *a*	2310·6	6 *a*	2365·1	1 *a s*	2410·2	4 *s*	2449·6
5 *a*	2260·4	5 *a*	2311·0	5 *s*	2365·3	1 *a s*	2410·7	6 *a* 4 *s*	2450·0
5 *a*	2260·7	6 *a*	2311·6	3 *a s*	2366·2	6 *a*	2411·4	6 *a*	2450·7
6 *a*	2262·4	6 *a*	2312·0	2 *a* 1 *s*	2368·2	1 *a s*	2413·0	6 *a* 5 *s*	2451·0
6 *a*	2262·8	2 *a*	2312·7	4 *a*	2369·1	6 *a s*	2413·8	6 *a*	2451·3
6 *a*	2263·2	6 *a*	2313·6	5 *s*	2369·6	6 *a s*	2414·8	6 *a*	2451·8
5 *a*	2264·2	6 *a*	2316·7	4 *a s*	2370·1	6 *a*	2415·4	6 *a*	2452·3
5 *a*	2264·7	5 *a*	2317·5	4 *a*	2371·1	6 *a* 5 *s*	2416·3	6 *s*	2452·9
6 *a*	2265·7	6 *a*	2317·7	4 *s*	2372·3	6 *a*	2417·1	3 *a*	2453·2
6 *a*	2266·6	5 *a*	2319·2	6 *a*	2372·7	6 *a* 2 *s*	2417·5	5 *s*	2453·5
5 *a*	2266·8	6 *a*	2319·6	4 *s*	2373·3	6 *a* 5 *s*	2418·2	6 *s*	2453·8
3 *a*	2267·2	3 *a*	2319·9	2 *a* 1 *s*	2373·4	3 *a*	2418·9	3 *s*	2454·3
6 *a*	2268·8	2 *a* 1 *s*	2326·9	6 *a*	2374·1	6 *a*	2419·4	6 *a*	2455·3
4 *a*	2270·5	6 *a*	2329·3	2 *a* 1 *s*	2374·9	6 *s*	2419·7	6 *s*	2455·7
4 *a*	2271·5	2 *a* 1 *s*	2330·9	6 *a* 3 *s*	2376·2	6 *a*	2420·0	6 *a*	2456·0
4 *a*	2271·8	2 *a* 1 *s*	2332·5	6 *a*	2376·9	6 *a*	2420·7	6 *s*	2456·4
4 *a*	2272·5	6 *a*	2333·1	6 *a*	2377·6	6 *a*	2421·3	2 *a* 5 *s*	2457·4
4 *a*	2273·8	6 *a*	2334·2	6 *s*	2378·2	6 *a* 3 *s*	2422·4	6 *a*	2458·2
4 *a*	2274·9	6 *a*	2334·5	6 *s*	2378·8	6 *a* 4 *s*	2422·9	6 *a* 1 *s*	2458·5
6 *a*	2275·2	6 *a*	2334·8	2 *a* 1 *s*	2379·0	5 *a* 1 *s*	2423·8	6 *a* 4 *s*	2460·2
4 *a*	2275·7	2 *a* 1 *s*	2337·7	2 *a* 1 *s*	2380·5	6 *s*	2424·3	6 *a*	2460·8
4 *a*	2276·9	2 *a* 6 *s*	2339·0	1 *a s*	2381·7	6 *a s*	2425·0	6 *a* 3 *s*	2461·0
4 *a*	2277·5	3 *a*	2339·3	3 *a s*	2382·7	6 *a* 5 *s*	2425·4	3 *s*	2461·4
3 *a*	2279·7	5 *a* 6 *s*	2340·0	2 *a s*	2383·0	6 *s*	2427·0	3 *a*	2461·9

LIST of ultra-violet iron lines—(continued).

2 a 6 s	2462·3	6 s	2507·9	5 s	2554·8	6 a	2608·2	6 a	2672·4
6 a 4 s	2462·8	5 a	2508·5	6 a	2554·9	6 a s	2608·7	6 a	2674·6
5 a	2463·4	5 s	c 2508·8	5 s	2555·2	6 a	2609·1	6 a	2675·1
4 s	2463·7	2 a 5 s	2510·6	6 a	2556·0	6 s	2609·3	6 s	2676·1
4 s	2464·5	6 a 1 s	c 2511·4	6 a	2556·6	6 a	2610·3	6 a	2677·2
3 a 4 s	2464·7	6 a	2511·6	6 s	2557·2	6 a s	2610·7	2 a 6 s	2678·5
3 s	2465·4	3 a	2512·0	6 a	2558·3	1 a s	2611·4	6 a	2679·9
5 a 2 s	2466·4	3 a 4 s	2512·2	6 s	2558·9	6 a	2612·3	5 s	2680·4
5 a	2467·2	6 a	2513·2	5 s	2559·6	1 a s	2613·3	6 a	2680·8
5 s	2467·8	3 a s	c 2514·1	6 a 4 s	2560·0	6 a	2614·0	6 a	2681·5
3 a 6 s	2468·4	6 a	2514·3	6 a	2560·3	6 a	2615·0	5 s	2682·0
3 s	2469·0	4 s	2514·7	6 a	2560·9	1 a s	2617·2	5 s	2682·4
2 s	2470·3	1 a 6 s	c 2515·8	6 a	2561·5	6 a	2617·6	6 a	2683·5
6 a	2470·5	6 a	2516·3	6 a	2561·9	6 a	2618·3	6 a 1 s	2684·2
3 a 4 s	2471·9	6 a 3 s	2516·8	2 a s	2562·3	4 s	2618·6	6 s	2685·7
2 a 5 s	2472·4	5 a	2517·4	2 a s	2563·2	5 a s	2619·9	6 a	2686·0
6 a	2472·7	3 a 6 s	2517·8	6 a	2564·2	5 s	2620·4	6 a	2686·8
5 s	2472·9	6 a	2518·5	6 a	2565·1	3 a s	2621·2	6 a	2687·3
3 a s	2474·5	3 a s	c 2518·8	4 s	2566·0	6 s	2622·6	3 a s	2688·8
6 s	2474·9	5 a 6 s	2519·3	3 a s	2566·7	3 a 6 s	2623·1	5 a	5689·3
6 s	2475·5	6 a 3 s	2520·8	5 s	2568·1	6 a	2623·6	5 a	2689·5
6 a	2475·8	6 a 3 s	2521·5	6 a s	2568·6	1 a s	2625·2	6 a	2690·9
6 s	2476·0	1 a 2 s	2522·5	6 a s	2569·4	6 a s	2626·2	6 s	2691·2
5 a 6 s	2476·5	5 a 6 s	2523·3	5 a	2570·1	6 a	2626·8	6 a	2691·7
5 s	2477·1	2 a 6 s	c 2523·9	4 s	2570·6	1 a s	2627·9	6 a 1 s	2692·1
6 s	2477·9	5 a	2524·7	6 s	2571·2	6 a 5 s	2629·2	6 s	2693·4
1 a 3 s	2478·3	6 a 2 s	2525·1	6 a	2572·5	6 a 5 s	2629·7	5 a	2694·0
6 s	2479·0	5 a 2 s	2526·0	6 s	2572·8	1 a s	2630·7	6 a	2694·4
6 a	2479·2	5 s	2526·7	6 a 3 s	2574·0	1 a s	2631·0	6 s	2694·7
2 a 6 s	2479·5	2 a 5 s	2527·1	6 a	2574·8	5 a 6 s	2632·0	5 a	2695·0
6 a 2 s	2480·0	6 a	2527·9	5 a	2575·3	6 a	2632·3	4 a	2695·6
6 s	2480·7	6 a	c 2528·1	4 a 6 s	2575·7	5 s	2632·9	6 a	2695·9
6 s	2481·3	3 a 6 s	2528·9	3 a	2576·2	6 s	2635·1	6 a	2696·6
6 a 3 s	2481·8	2 s	2529·2	4 s	2576·5	3 a 6 s	2635·5	4 s	2697·0
3 s	2482·4	3 a	2529·6	3 a s	2577·4	6 a s	2636·1	6 a	2697·7
1 a 6 s	2482·9	6 s	2529·9	6 a	2578·3	6 a	2636·6	4 a 5 s	2698·6
6 s	2483·3	4 a 6 s	2530·4	6 a	2578·7	3 s	2637·3	6 s	2699·8
3 a s	2483·7	6 a	2531·1	6 s	2578·9	4 s	2639·2	6 a 6 s	2701·2
6 a	2484·7	5 a 6 s	2532·0	6 a	2579·3	6 s	2640·7	6 a	2702·6
6 a	2485·7	6 a	2532·4	6 a	2579·5	4 a 6 s	2641·4	1 s	2703·6
5 a 2 s	2486·1	6 a	2532·6	6 a	2579·9	6 s	2641·7	3 a	2705·6
5 a	2486·4	3 a 2 s	2533·4	6 a	2580·3	3 a 6 s	2643·8	1 a 3 s	2706·0
5 a	2486·8	6 a 2 s	2534·2	6 s	2580·6	6 a 3 s	2644·9	6 a 4 s	2706·7
5 a	2487·1	2 a 3 s	2535·2	6 a	2580·9	5 a	2645·2	3 a	2708·1
1 a 3 s	2487·7	5 a 1 s	2536·6	4 a	2581·7	6 s	2645·8	4 s	2708·7
6 a	2488·7	3 a	2536·9	4 a 3 s	2582·0	4 a 6 s	2647·3	6 a s	2709·7
4 s	2489·2	4 s	2538·0	2 a 6 s	2584·0	4 s	2649·2	4 a 6 s	2710·1
1 a 2 s	2489·5	5 a 1 s	2538·6	1 a s	2585·4	6 a 5 s	2650·4	3 a 4 s	2711·2
1 a 2 s	2490·5	6 a	2539·1	3 a s	2587·5	6 a	2650·9	3 s	2711·5
2 a	2491·0	5 s	2540·4	6 s	2588·2	6 s	2652·2	6 s	2711·9
3 s	2491·1	2 a 4 s	2540·8	6 s	2590·0	6 s	2653·3	6 a	2713·5
6 a s	2492·0	4 s	c 2541·6	3 a s	2591·0	6 s	2654·4	1 a s	2713·8
3 a 1 s	2492·9	3 a 6 s	2541·7	6 a	2591·7	5 a s	2655·7	6 a	2714·4
5 a s	2493·7	6 s	2542·4	3 s	2592·2	6 a	2656·4	6 a	2714·9
6 a	2493·9	6 a 3 s	2543·0	3 a s	2593·1	6 a 3 s	2657·8	6 a 3 s	2715·7
5 a 4 s	2495·6	3 a 6 s	2543·7	6 a	2593·5	5 a	2660·8	6 a	2717·4
3 a 6 s	2496·3	4 a	2544·5	6 s	2594·5	4 a 6 s	2661·6	2 a 6 s	2718·0
6 a 2 s	2497·5	5 s	2544·9	6 a	2595·2	6 s	2662·2	1 a 3 s	2718·5
6 a 1 s	2498·7	2 a 6 s	2545·8	6 a	2596·0	5 a	2663·5	5 a	2719·7
4 s	2500·7	5 a s	2546·6	1 a s	2597·8	6 a	2664·0	1 a 4 s	2720·3
2 a 6 s	2500·9	6 s	2547·0	1 a s	2598·9	6 a 1 s	2664·2	6 s	2721·5
5 a	2501·4	6 a	2547·8	6 a	2599·7	5 a	2665·7	6 s	2721·7
6 a 2 s	2502·1	5 s	2548·4	6 a	2603·5	1 a s	2666·1	5 s	2722·3
6 a	2503·0	5 s	2549·0	6 s	2603·8	6 s	2666·7	1 a 4 s	2723·1
3 s	2503·1	5 s	2549·1	6 a	2604·4	6 a	2667·2	5 a 3 s	2724·3
3 s	2503·6	2 a	2549·2	5 s	2604·9	6 s	2668·5	5 a	2725·5
6 a s	2504·9	5 s	2549·7	5 s	2605·1	6 a	2668·7	6 s	2726·0
6 a	2505·2	5 s	2550·3	3 a	2605·3	6 s	2669·2	4 a 1 s	2727·1
3 s	2505·8	6 a s	2550·8	6 s	2605·6	6 s	2669·7	6 a	2727·5
6 a	2506·2	6 a	2552·3	5 s	2606·1	6 a	2669·9	6 a 5 s	2728·3
3 a 6 s	c 2506·6	6 a s	2552·8	6 a s	2606·5	6 s	2670·8	6 s	2729·1
3 a 6 s	2507·6	6 s	2553·4	3 a s	2606·7	6 a 5 s	2671·8	5 a 3 s	2730·2

LIST of ultra-violet iron lines—(continued).

6 *s*	2731·5	6 *s*	2764·7	6 *a s*	2803·2	6 *a* 4 *s*	2848·0	5 *a s*	2894·0
6 *s*	2732·5	6 *s*	2765·3	6 *s*	2803·8	6 *a s*	2848·2	5 *a* 4 *s*	2894·5
2 *a* 4 *s*	2733·1	6 *a*	2766·8	6 *a* 5 *s*	2804·2	6 *s*	2849·3	5 *s*	2896·7
6 *a*	2733·7	3 *a* 1 *s*	2767·2	6 *s*	2804·9	6 *s*	2855·3	6 *a*	2897·8
6 *a*	2733·9	6 *a* 4 *s*	2768·8	6 *s*	2805·4	6 *s*	2856·7	5 *a*	2898·9
3 *a* 5 *s*	2735·0	6 *a* 4 *s*	2769·1	3 *a* 6 *s*	2806·7	4 *s*	2857·9	5 *a*	2900·8
5 *a* 1 *s*	2736·5	6 *a*	2769·4	6 *a*	2807·9	6 *a*	2858·3	5 *a*	2901·3
3 *a* 6 *s*	2736·9	6 *a s*	2770·3	6 *a s*	2809·7	6 *s*	2860·9	6 *s*	2902·1
1 *a s*	2739·1	6 *s*	2771·1	6 *s*	2810·9	6 *s*	2862·1	6 *a*	2903·5
5 *s*	2741·1	2 *a* 5 *s*	2771·9	6 *a*	2811·7	6 *a*	2862·4	6 *a s*	2905·8
1 *a* 5 *s*	2742·0	6 *a*	2773·1	6 *s*	2812·2	4 *a*	2863·1	6 *a s*	2907·1
3 *a* 2 *s*	2742·8	6 *a* 5 *s*	2774·5	2 *a* 4 *s*	2812·8	4 *a*	2863·6	6 *a*	2908·2
6 *a*	2743·3	6 *s*	2776·1	6 *s*	2813·4	6 *s*	2864·7	6 *a*	2908·9
3 *a* 5 *s*	2743·7	6 *s*	2776·9	6 *a*	2815·1	5 *a*	2866·2	6 *s*	2910·5
5 *a*	2744·2	6 *s*	2777·7	6 *a s*	2817·0	6 *s*	2866·5	1 *a* 6 *s*	2911·5
2 *a* 3 *s*	2746·1	4 *a* 5 *s*	2777·9	6 *a s*	2819·0	6 *a*	2867·1	6 *a*	2913·6
2 *a s*	2746·6	6 *a*	2778·3	6 *a*	2820·4	6 *a*	2868·0	5 *a* 6 *s*	2917·4
1 *a s*	2749·0	6 *a* 2 *s*	2778·9	3 *a* 6 *s*	2822·9	3 *a* 6 *s*	2869·0	6 *a*	2920·0
2 *a* 5 *s*	2749·8	5 *a* 6 *s*	2781·6	6 *a*	2823·9	6 *s*	2870·7	6 *s*	2921·5
6 *a*	2750·6	1 *s*	2783·4	3 *a* 6 *s*	2825·1	4 *a* 5 *s*	2872·0	6 *a s*	2922·8
5 *s*	2750·8	6 *a*	2784·2	6 *s*	2827·0	4 *s*	2873·0	6 *a*	2923·2
6 *s*	2752·1	3 *s*	2785·1	6 *a s*	2827·3	3 *a*	2873·6	6 *a*	2924·7
6 *a* 1 *s*	2753·0	1 *a* 3 *s*	2788·0	6 *a* 5 *s*	2828·3	6 *a* 5 *s*	2874·9	6 *a*	2925·2
6 *a*	2753·5	6 *a*	2789·5	2 *s*	2831·0	6 *s*	2876·4	6 *a* 2 *s*	2926·0
6 *a*	2753·9	6 *s*	2790·3	3 *a* 6 *s*	2831·8	4 *a*	2876·8	1 *a* 4 *s*	2928·3
6 *a*	2754·3	6 *a*	2791·5	5 *a*	2832·4	4 *a*	2878·2	6 *s*	2931·1
1 *a s*	2755·5	6 *a*	2792·2	5 *a*	2832·8	6 *a* 5 *s*	2880·4	5 *a* 6 *s*	2932·4
3 *a*	2756·2	4 *s*	2793·3	3 *s*	2835·2	6 *a* 4 *s*	2883·3	1 *a* 5 *s*	2936·4
6 *s*	2756·9	3 *a*	2794·5	6 *s*	2836·7	6 *s*	2885·5	5 *a*	2937·3
4 *a*	2757·2	6 *s*	2796·3	5 *a* 6 *s*	2837·7	6 *a*	2885·8	4 *a* 6 *s*	2938·7
6 *a*	2759·7	5 *a s*	2797·4	6 *a*	2839·6	6 *a*	2887·3	6 *a*	2939·9
3 *a s*	2761·7	3 *a*	2797·9	6 *a* 3 *s*	2840·3	6 *s*	2887·6	2 *a*	2940·8
4 *a*	2761·9	6 *a* 4 *s*	2798·8	6 *a s*	2843·1	6 *a*	2889·2	6 *a*	2943·1
6 *s*	2762·4	6 *a*	2799·4	2 *a* 4 *s*	2843·6	6 *a*	2891·2	6 *a* 2 *s*	2944·0
4 *a*	2763·0	6 *a*	2800·1	5 *a* 4 *s*	2845·3	6 *a*	2892·0	6 *a*	2944·6
6 *s*	2763·6	3 *a*	2800·8	6 *a*	2846·5	6 *a*	2893·2	U	2947·3
6 *a*	2764·0	6 *a*	2801·8						

The accompanying map is drawn to a scale double that of ÅNGSTRÖM'S and CORNU'S maps of the solar spectrum. Those lines which are common to both arc and spark are drawn right across from top to bottom, while those which are in the arc only are not continued to the bottom, and those which are in the spark only do not begin at the top; so that the upper portion of the map represents the arc spectrum, the lower the spark spectrum, and they overlap in the middle.

We do not pretend to say that every line in this map really belongs to iron, for commercial iron wire was used to produce it, and the map may therefore probably include lines of a good many metals, certainly manganese lines in the arc, but it will not the less serve the purpose for which it has been made, namely: for reference in determining the approximate wave-lengths of lines of any spectra.

PART II.

(Received June 15, 1882.)

The account of the ultra-violet spectra of fifteen metals here recorded is a first instalment of the results of observations which we have accumulated during the past three years, but have not heretofore been able to reduce. During that time we have taken some thousands of photographs of the electric arc under various conditions, and especially in crucibles of lime and magnesia (as previously described by us), and in the presence of most of the known metals; but with the exception of CORNU'S map of the ultra-violet solar spectrum giving the chief iron lines and a few of those of other elements, up to the line U we have had little to aid us in the exploration of a new field and the assignment of the several lines to the elements producing them, and the measurement of our many photographs has cost both time and patience. Dr. W. A. MILLER long ago published an account of his photographs of the spark spectra of the elements, and Mr. HARTLEY has recently (Trans. Roy. Dublin Soc.) published photographs of the spark spectra of several elements which are a great improvement on those previously published. But those give spark spectra only, are taken with an apparatus of small dispersion, and are not reduced to scale, so that they give qualitative rather than quantitative results. The spectra which we here describe are those of the arc up to the wave-length 2200, and we give in each case the approximate wave-lengths of the lines observed. For some few of the lines of tin and aluminium the wave-lengths have been determined by means of a grating as described in the first part of this paper, but in all other cases they have been derived by interpolation from the wave-lengths of the neighbouring iron lines. In the map which accompanies this paper we have given in the top line the principal lines of iron for convenience of reference, and in the lowest line the arc lines of carbon with which it is necessary to be acquainted as they are always present, though varying much in intensity, in the arc taken between carbon electrodes. The scale of this map is one-half that of ÅNGSTRÖM'S "Normal Solar Spectrum."

We have already, in describing the visible spectra of the alkali metals and that of magnesium, called attention to probable harmonic relations between the lines. This relation manifests itself in three ways—first, by the repetition of similar groups of lines; secondly, by a law of sequence in distance, producing a diminishing distance between successive repetitions of the same group as they decrease in wave-length; and thirdly, a law of sequence as regards quality, an alternation of sharper and more diffuse groups, with a gradually increasing diffuseness and diminishing intensity of all the related groups as the wave-length diminishes.

The first relationship has long since been noticed in the case of the sodium lines which recur in pairs, and we have observed that the potassium lines between the extreme red and violet pairs are repetitions of a quadruple group, while the lithium lines (with the exception of the blue line mentioned below) are single, and one set of those of magnesium triplets. We now record a second harmonic* series of potassium lines which appear to be pairs, and the violet pair, and possibly the red pair too, belong to this series. Lithium shows a second harmonic series of single lines high up on the scale. Calcium gives a long series of well marked triplets; zinc likewise gives a series of triplets; aluminium gives pairs, and in the highest region triplets; thallium gives a series which seem to be quadruple groups with two of the four lines in each of much greater intensity than the rest. The alternations of sharper and more diffuse groups are generally apparent and are very marked in the cases of calcium and zinc. The diminishing distance and intensity and increasing diffuseness of successive repetitions of the same group as the wave-length diminishes, are in all the cases mentioned very plain. In all these cases the different lines forming a group are tolerably close to one another, so that successive repetitions of a group do not overlap one another, but it may be that in other cases the lines forming one group may be so far apart that the most refrangible line of one group may be more refrangible than the least refrangible line of the next repetition of the group; the groups and their sequence will thus be much less easily recognised.

Potassium.

The ultra-violet spectrum of potassium, so far as we have observed it, is apparently one harmonically related series of which the first member above the visible spectrum is a double line just below the solar line O; the next falls between Q and R, and the others follow at decreasing intervals, the seventh and last that we have observed falling just above U. It is only in the case of the line near O that we have been able to make sure that it consists of a pair of lines, but it is very probable that all are pairs in reality; all are strongly reversed, as might be expected from the volatility of the metal, and expanded when a fresh quantity of the metal or its compounds is introduced into the arc, so that the separation of the pairs, if such they be, could not be seen, while the more refrangible lines die away and are not recognisable as *bright* lines amongst the many lines which come out in the arc, as the alkali metal is dissipated. The line between Q and R, which is a strong line, happens to be in a region where the lines of iron, manganese, and chromium lie very closely, so that we cannot pronounce with certainty that it is a double line.

* By an "harmonic series" of lines we merely mean a series of overtones of a fundamental vibration we do not mean that they follow the simple arithmetical law of an ordinary harmonic progression, but are comparable rather with the overtones of a bar or bell than with those of a uniform stretched string.

POTASSIUM lines.

Approximate wave-length.	Remarks.
3445·0 } 3443·6 }	Double line.
3216·5	All are easily reversed.
3101·0	
3033·0	
2992·0	The lines become weaker as they are more refrangible.
2963·4	
2942·0	

Sodium.

The sodium lines observed by us also form one apparently harmonic series with the double line, wave-length 3301, observed by CORNU. In this case also we have not been able to make out that any of the lines above 3301 are double, as when there is enough sodium present to develop them decidedly they are always more or less diffuse and reversed. Indeed, the line at 3301 is a very close pair and it is not often seen as two lines.

One line is so near to the very strong magnesium line, wave-length 2852, that the apparent development of the magnesium line by sodium was for some time an enigma to us. The sodium line is a little less refrangible than the magnesium line.

SODIUM lines.

Approximate wave-length.	Remarks.
3301·0	CORNU's double line.
2853·3	All the lines are easily reversed.
2679·0	
2593·3	

Lithium.

We have already described one apparently harmonic series of lithium lines extending into the ultra-violet up to about wave-length 3799. This series we described as all single lines though alternately sharp and diffuse. This description is correct, except that we have since found that one line of the series, namely, the strong blue line at wave-length 4604, is really a double line. When a fresh dose of lithium, or of some one of its compounds, is introduced into the arc, a second weaker line comes out on the more refrangible side of the strong blue line, and gives to it all the appearance of a reversal with an expansion of the bright wings unequally extended on the two sides. As the strong blue line is, however, often really reversed, the effect is then that of a double reversal, that is to say, the appearance is that of a broad bright band with a narrower dark band within it and a bright line in the middle of the dark band. The second line rather quickly dies out as the lithium evaporates, leaving the strong blue line comparatively permanent. We have never observed any such second line, or companion, to any of the other lines of lithium. The new series begins with a line at wave-length about 3232, and dies out with a very diffuse line at about wave-length 2359. The following is a list of the ultra-violet lines we have observed.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3984·5		2561·5	Reversed.
3913·5	Diffuse.	2475·0	"
3862·3	{ Somewhat obscured by the	2425·5	
3799·0	{ cyanogen bands in this region.	2394·5	Diffuse.
3232·0		2373·5	Very diffuse.
2741·0	Reversed.	2359·0	Very diffuse and weak.

Barium.

The barium lines are numerous, but do not fall into easily recognised harmonic series.

BARIUM lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3991·8		3320·9	
3908·5		3279·8	
3891·0		3261·0	
3793·5		3070·3	
3660·7		2785·1	
3598·7		2771·0	
3592·8		2739·0	
3579·1		2702·0	
3544·0		2647·0	
3524·5		2634·5	
3499·2	Very strong, reversed.	2596·7	
3419·3		2542·7	
3375·6		2347·0	Strong.
3354·8		2335·0	Very strong.
3347·7		2304·5	Strong.

Strontium.

Strontium, and its compounds, produce a line at wave-length 3705 coincident, or nearly so, with one of the lines ascribed to calcium by CORNU. We have so often observed this line much reinforced by strontium without any increase of the other calcium lines which are always present in the arc from calcium in the carbon electrodes, that we think we are justified in putting down a strontium line at this place. Two other lines of this metal are close to, but not coincident with lines of barium.

STRONTIUM lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3705·0	Coincident or nearly so with a calcium line.	3458·0	Diffuse.
3653·0		3379·5	
3547·0		3364·8	
3527·0		3305·2	
3498·0		2931·1	
3464·0			

Calcium.

CORNU has mapped two calcium lines, one on either side of the solar line M, and four other lines, of which one is coincident with the solar line R, one slightly less refrangible, and the other two more refrangible. One of these lines, at wave-length 3168·5, we have never certainly seen, but the others are well developed when calcium compounds are put into the arc. Besides these we have always seen when calcium, or one of its compounds, is present in moderate quantity a series of triplets analogous to those of magnesium. Each triplet consists of two strong lines with a rather weaker line on their more refrangible side. This series appears to be harmonically related to the well-known blue triplet at wave-length 4454–24. The first repetition of this triplet occurs close to H, one line of the triplet falling below H, while the other two lines fall between H and K. The next triplet falls between N and M, and the next between O and N, and so on at decreasing intervals, the most refrangible repetitions becoming very faint and diffuse, so that in the last, a little below S, we have only been able to distinguish the strongest two lines of the triplet. The triplets are alternately diffuse and sharp, those near H, between O and N, and so on alternately, being the sharper. The diffuse triplets are stronger than the others and more easily reversed. Beyond this series we have noticed only one calcium line, and that is high up on the scale, at wave-length about 2398.

CALCIUM lines.

Approximate wave-lengths.	Remarks.	Approximate wave-lengths.	Remarks.
3967·7	H.	3285·0	
3972·3		3273·5	Sharp triplet.
3956·0	Sharp triplet.	3268·5	
3947·9		3224·5	
3933·0	K.	3213·0	Diffuse triplet.
3736·4	Mapped by CORNU.	3208·0	
3705·5	Ditto.	3181·0	Mapped by CORNU.
3644·0	Very strong.	3179·0	R. ditto.
3631·0	Readily reversed.	3168·5	Ditto, not seen by us.
3623·5		3158·8	Mapped by CORNU.
3486·5		3151·0	
3474·5	Sharp triplet.	3141·0	
3468·0		3136·0	
3359·5		3117·5	Weak, very diffuse.
3347·5	Very strong.	3108·0	
3342·0		2398·0	

Zinc.

Zinc is another metal which gives a well-marked apparently harmonic series of triplets, but the different lines of each group are further separated than in the calcium or magnesium triplets. The middle line of the first triplets confounds with the sodium pair wave-length 3301, but by reason of the diffuse character of the zinc line we have not been able to decide whether the coincidence is more than approximate.

ZINC lines.

Approximate wave-lengths.	Remarks.	Approximate wave-lengths.	Remarks.
3342·0		2608·5	
3301·0		2582·0	Diffuse.
3281·0		2569·7	
3070·0		2516·0	
3035·0		2491·5	
3017·0		2480·0	
2800·0		2464·5	
2770·0	Diffuse.	2440·0	Very diffuse.
2756·0		2430·0	
2713·3			
2684·0			
2670·5			

Mercury.

As might be expected from its volatility, it is difficult to obtain lines of mercury in the arc; but one line gives a reversed image of itself at wave-length 2536·8. This line is very bright in the flame of cyanogen, containing vapour of mercury.

Gold.

Gold also gives us but few lines. The three lines we record are perhaps harmonically related.

GOLD lines.

Approximate wave-length.	Remarks.
3122·8	
2675·4	Reversed.
2427·5	Ditto.

Thallium.

Groups of thallium lines manifestly similar to one another recur, and are probably harmonically related. This recurrence is more evident in the photographs in which the lines which are expanded and reversed by the introduction of fresh metal are at once recognised. The pairs at 2921, 2710, 2609, and the lines at 2552, 2517 seem to fall into one series.

THALLIUM lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3775·6		2714·6	Very diffuse.
3528·3		2710·4	} Reversed.
3517·8		2708·8	} Strong, diffuse reversed.
3228·1		2699·7	Very diffuse.
2943·9		2665·0	Diffuse.
2921·3	} Very strong.	2652·3	
2917·8	} Very strong.	2609·4	} Reversed.
2895·2		2608·6	} Strong, reversed.
2825·8		2552·0	Reversed.
2826·9		2517·0	Diffuse.

Aluminium.

The spectrum of aluminium is comparatively simple. The well-known pair of lines between H and K seem to be repeated twice in the region above without much, if any, diminution of strength, but we have not observed any such lengthened sequence of repetitions of these lines as we have of the lines of magnesium and other metals. Higher on the scale we come to another series of groups which are triplets, or perhaps quadruple groups, for the first and strongest group shows a faint fourth line which we have not observed in the succeeding groups. The repetitions we record are only two, but they lie in a part of the spectrum so near the limit of transparency of calcite that it is quite possible that there may be more beyond, which will show themselves when quartz prisms are used; a strong triplet near N appearing in the spark, wave-length about 3605, 3598, 3585, does not show in the arc so far as we have observed.

ALUMINIUM lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
2659·8 2652·0	Strong, frequently reversed.	2268·7 2263·1 2257·3	Strong, diffuse. " "
2574·5 2567·5	" " "	2216·0	
2378·4 2373·2 2366·9	A fourth faint line close to the middle line of this group. Middle line very strong, generally reversed.	2210·0	Strong, diffuse.
		2205·0	Diffuse.

Lead.

The lines of lead are numerous and strong, and many of them readily reversed. We have not yet traced any probably harmonic series amongst them.

Lead also gives some indefinite bands of continuous light about the region wave-length 2500.

LEAD lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
4019·0		2801·1	Often reversed.
3801·0		2721·0	
3739·3		2706·1	
3683·3	Strong, often reversed.	2697·0	Middle of a very diffuse band.
3670·7		2662·7	
3639·3	" " "	2650·5	Diffuse.
3572·0		2627·8	
3260·0	Nearly coincident with a line of tin.	2613·7	Strong, often reversed.
3238·6		2575·7	Very diffuse.
3219·6		2476·5	Strong, reversed.
3118·5		2446·1	" "
2981·0 2973·5 2967·0	Weak lines.	2443·7 2428·5 2411·5	" " " "
2872·0		2401·8	" "
2850·5	A little above the magnesium line, sometimes hidden by the expansion of the latter.	2399·4 2393·7 2388·8	 Very strong, reversed.
2832·9	Very strong and diffuse.	2332·0	
2822·5	Generally reversed.		

Tin.

Tin is remarkable for the number and strength of its lines in the higher region of the spectrum, while its lines of lower refrangibility are so feeble that we have never seen any in the arc in the visible part of the spectrum. CORNU has recorded one line at wave-length 3260, and we have had no difficulty in recognising this line, but a line very nearly in that place is also developed by lead when other tin lines are not developed, and we have not been able to perceive that these lines are separable in any of our photographs. Many of the higher lines of this metal are easily reversed, indeed are almost always reversed in our photographs.

TIN lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3326·0		2523·5	
3260·0	Given by CORNU.	2495·5	
3175·0		2493·5	
3141·7		2483·1	
3033·0		2429·5	
3008·5		2421·5	
2986·4		2407·9	
13·1		2392·5	
2862·8		2364·7	
2839·5		2357·7	
2813·5		2354·5	
2812·5		2334·3	
2787·5		2317·0	
2784·7		2286·9	
2779·5		2282·5	
2761·5		2275·4	
2660·7		2251·0	Strong, reversed.
2636·5		2245·8	Strong.
2593·5		2231·3	
2571·0		2210·7	
2557·5		2198·7	
2546·1		2194·1	
2530·7			

ANTIMONY lines.

Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
4032·0		2597·5	
3637·0	Close above a lead line.	2528·0	
3265·0		2426·0	
3230·8		2383·3	
3228·0		2313·0	Very strong, reversed.
3028·0		2310·0	
2876·5			

BISMUTH lines.

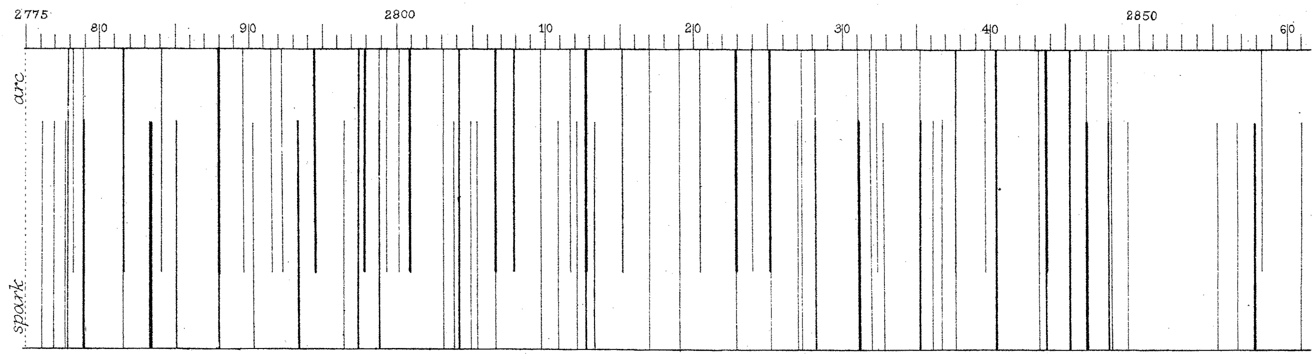
Approximate wave-length.	Remarks.	Approximate wave-length.	Remarks.
3595·3		2799·0	
3510·4		2780·0	
3396·2		2730·0	
3066·0	Very strong, often reversed.	2593·0	
3023·5		2524·0	
3000·0		2515·4	
2996·0		2448·0	
2937·4		2435·5	
2897·0		2431·0	
2862·0		2400·8	Very strong.
2810·0		2277·0	Weak, reversed.

Carbon.

In our map we give the carbon lines as developed in the arc. These occur in the arc taken between poles of purified graphite in air, and in nitrogen, and in carbonic acid gas, and they are always present in the arc taken in our crucibles. Most of them are also in the spark spectrum of carbon as described by us (Proc. Roy. Soc., xxxiii., 403), but some of the spark lines are not developed in the arc, and there are two lines in the arc which we did not notice in the spark.

CARBON lines.

Approximate wave-length.	Remarks.
2881·1	Not observed in spark.
2528·1	
2523·9	
2518·8	
2515·8	
2514·1	
2506·6	
2478·3	The strongest line.
2434·8	Not observed in spark.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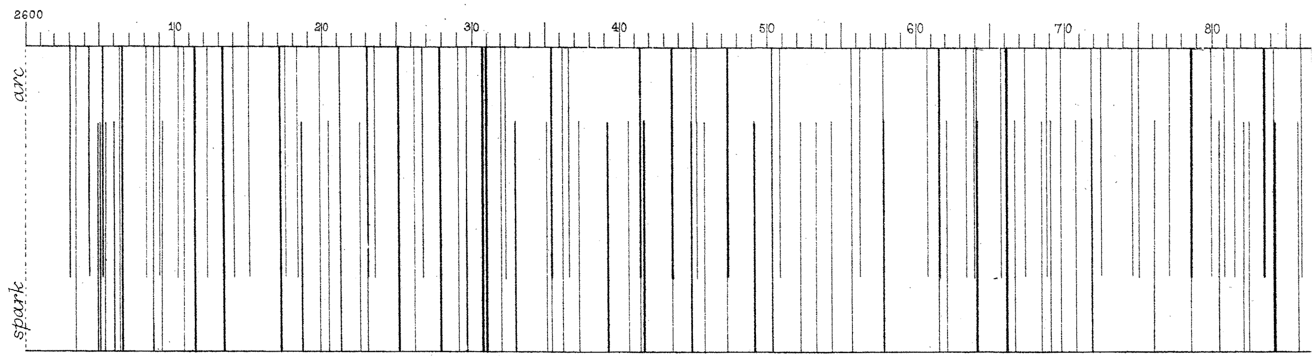
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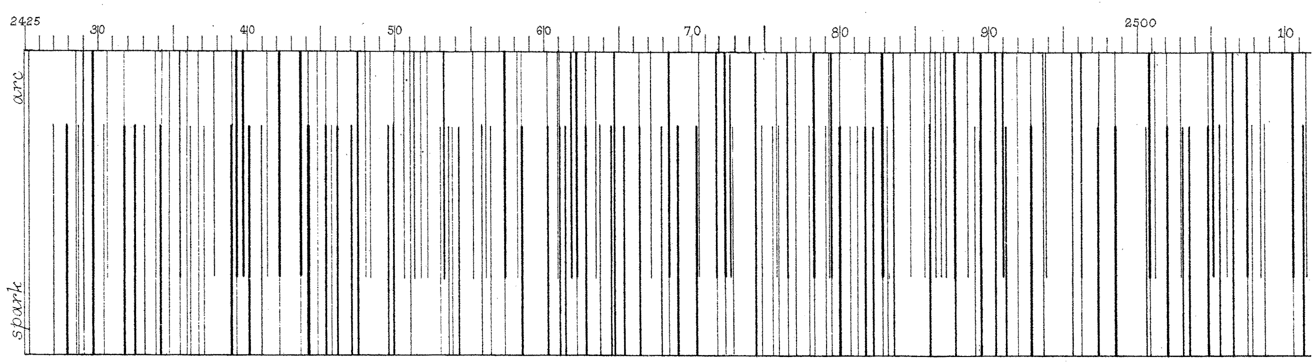
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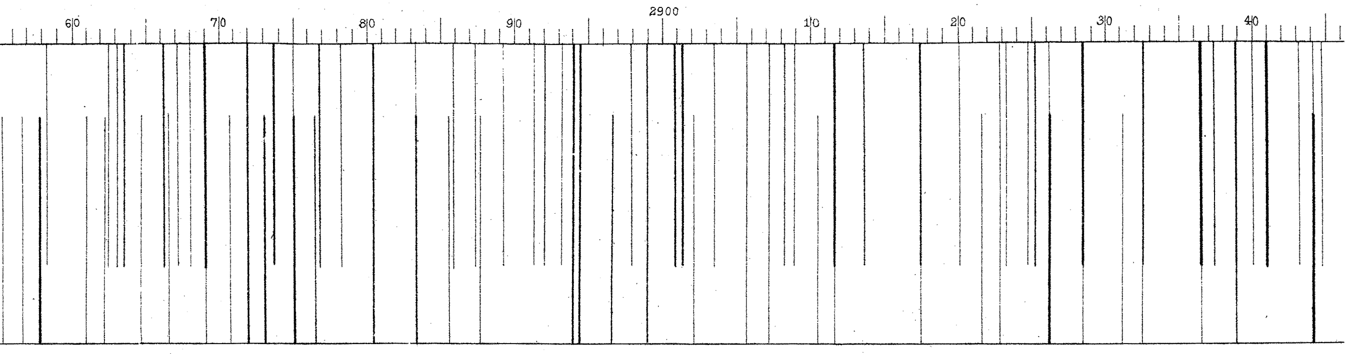
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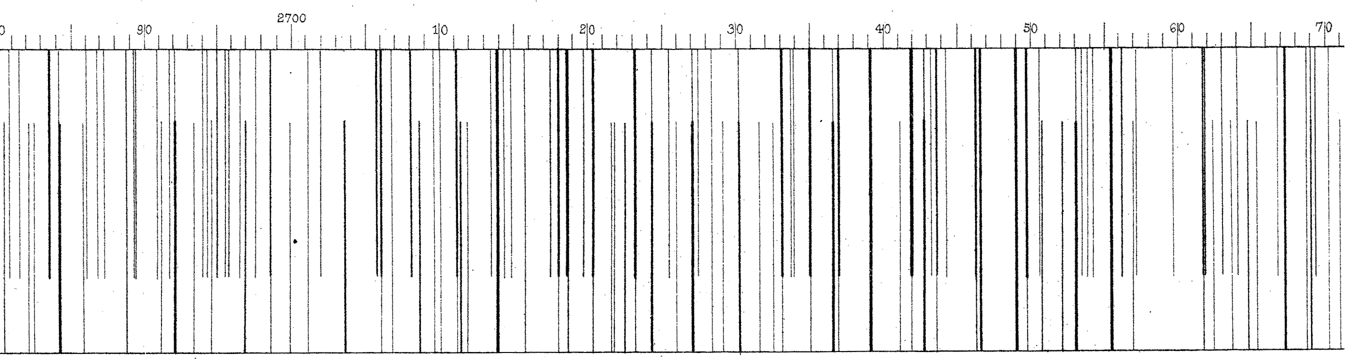
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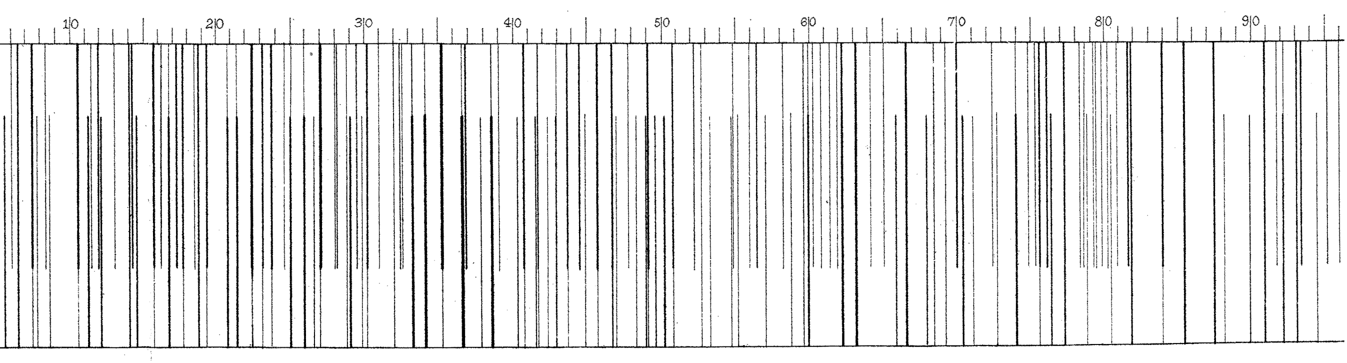
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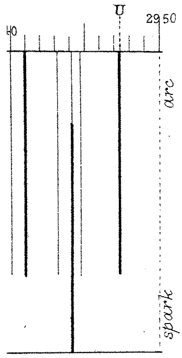

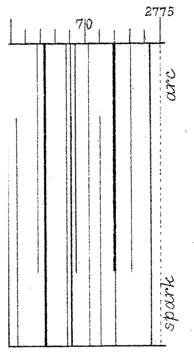

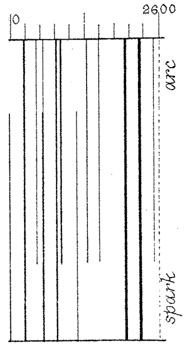

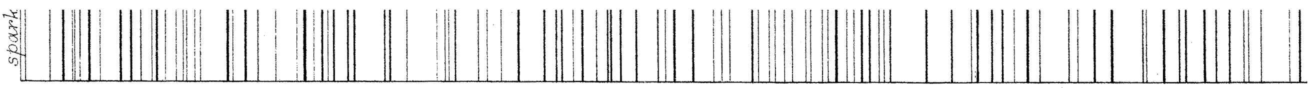
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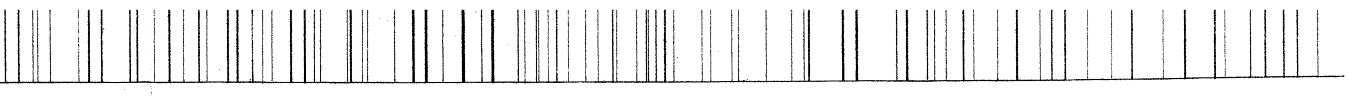

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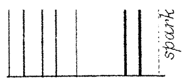

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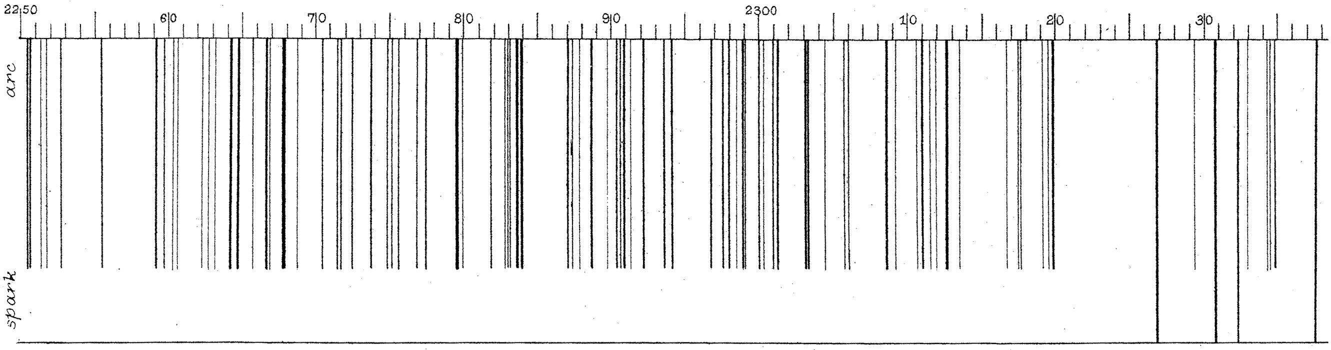

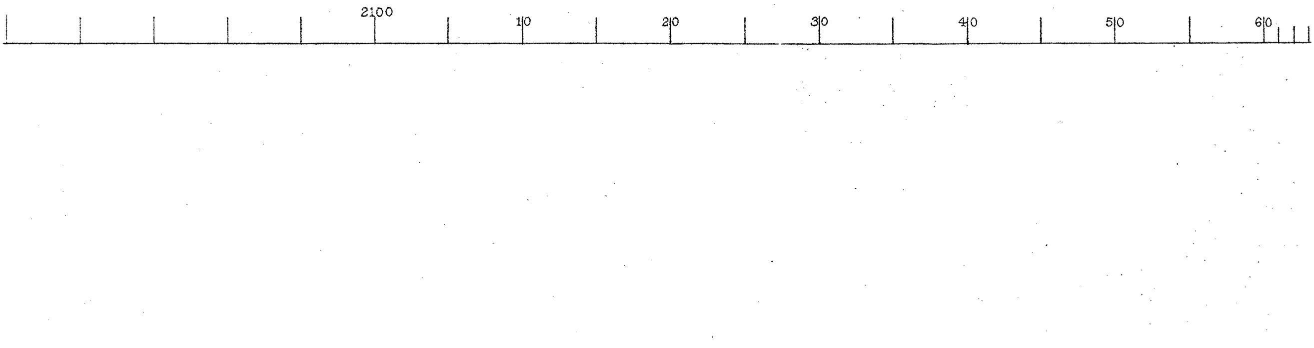

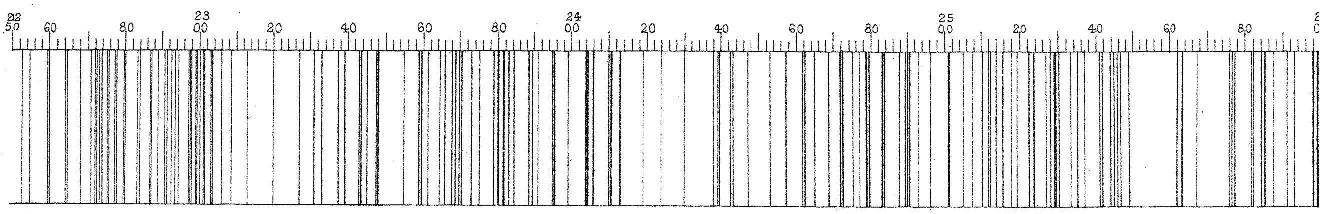

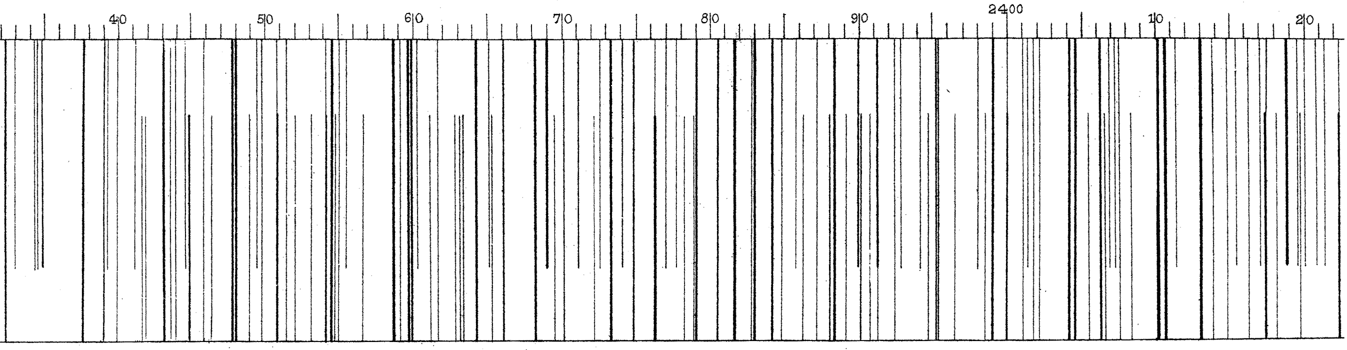

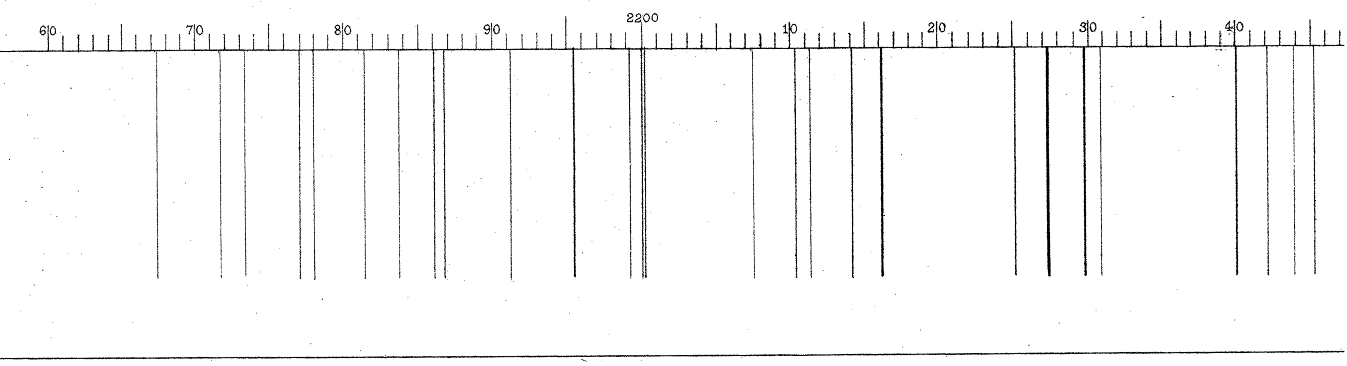

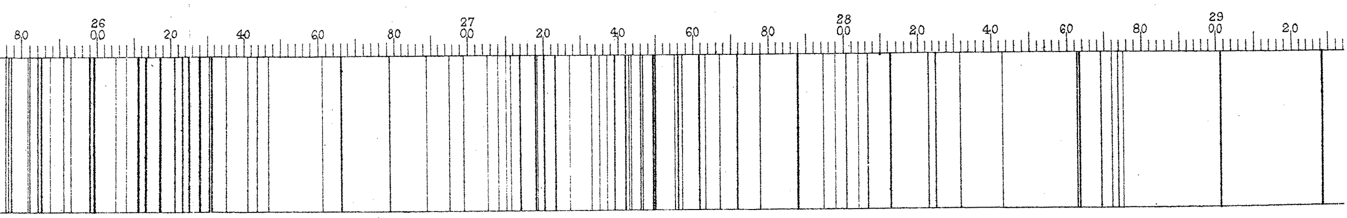

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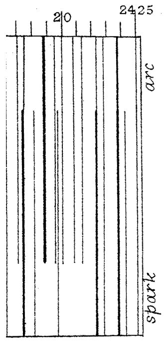
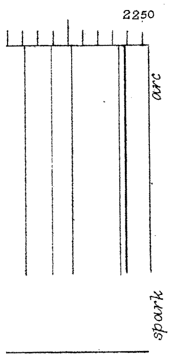
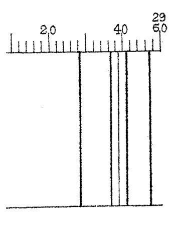
Plate 2.







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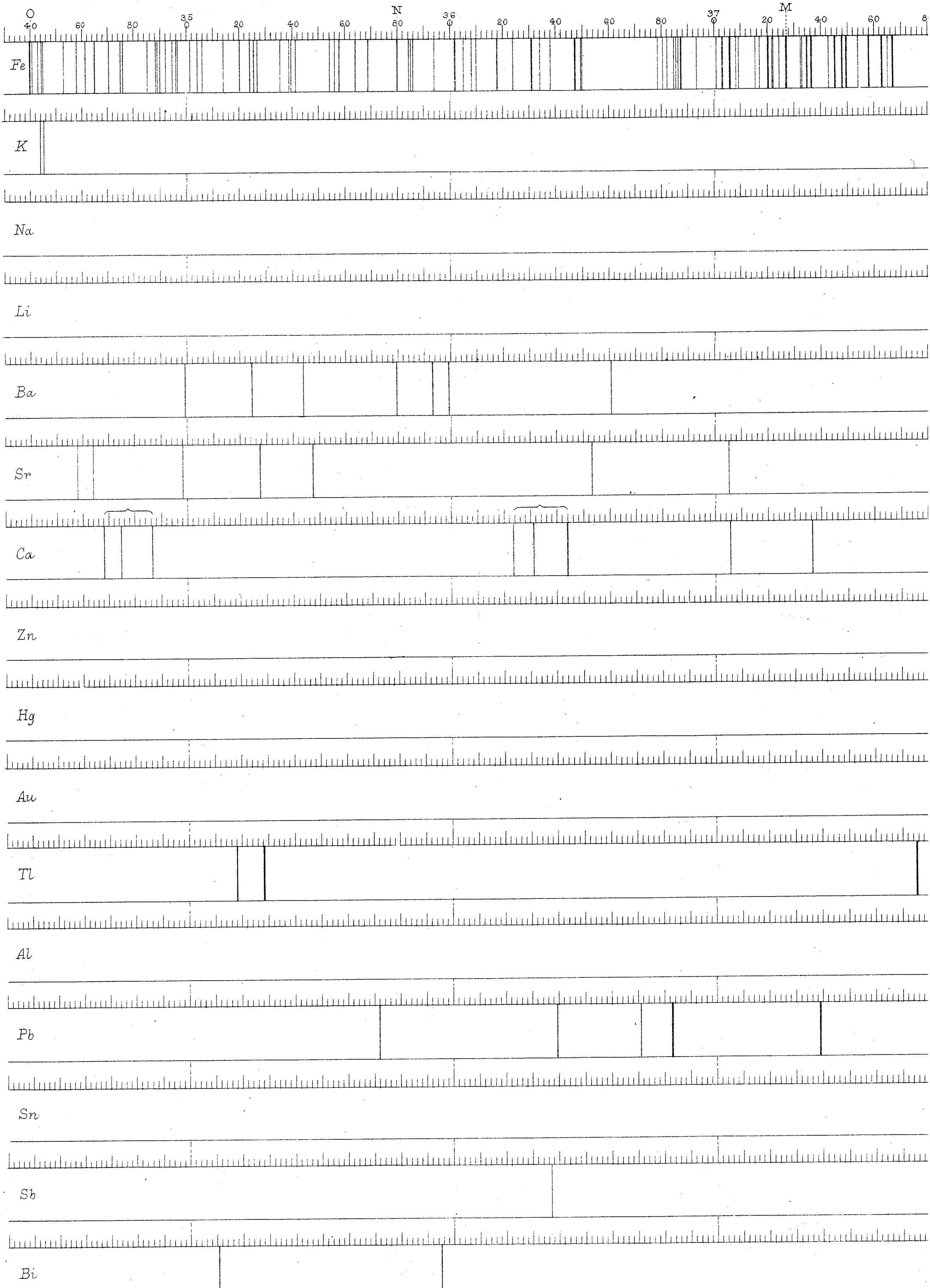

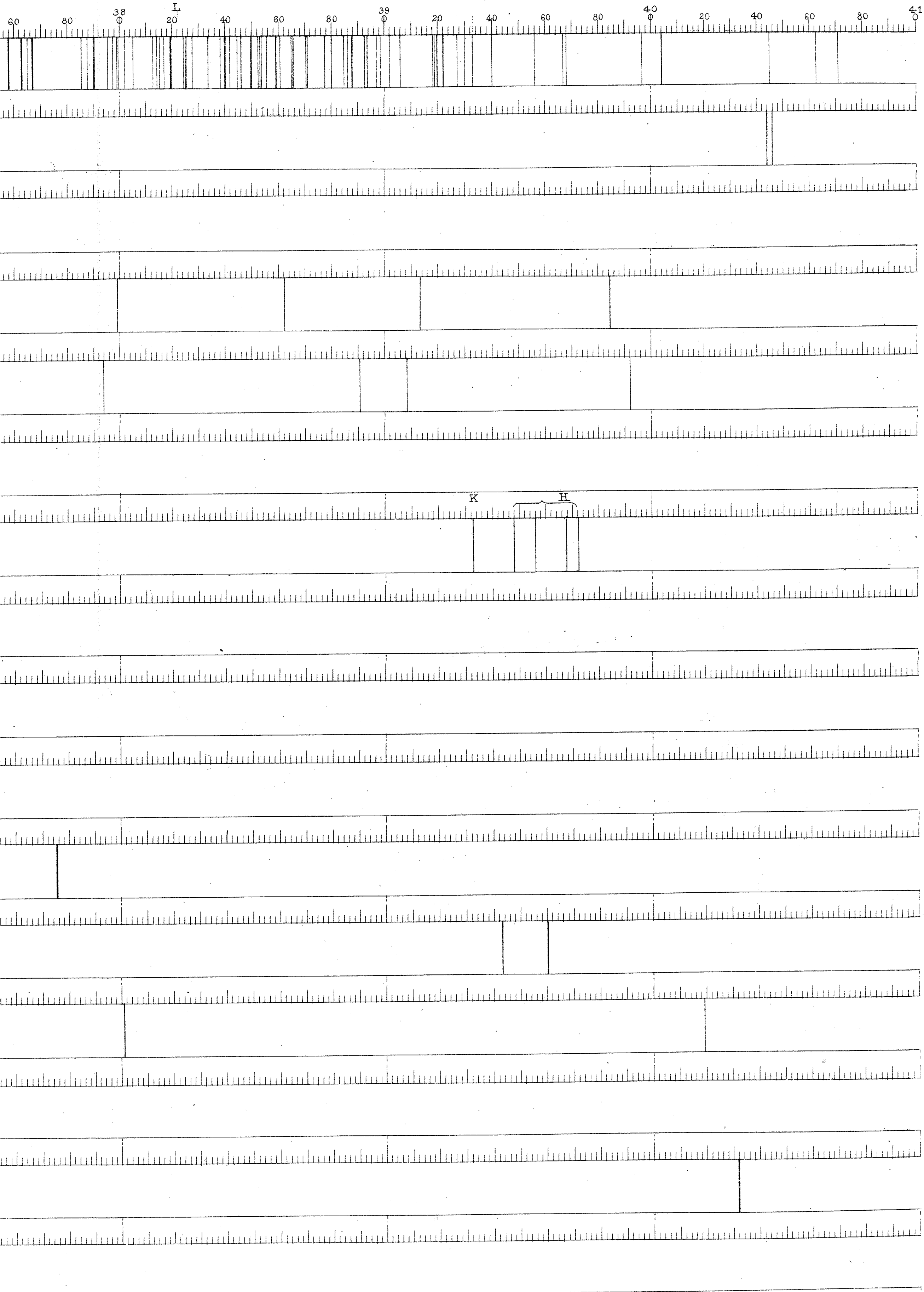
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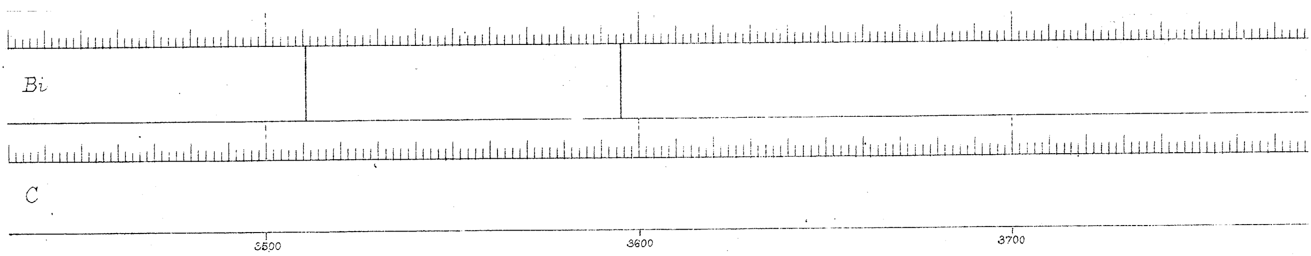
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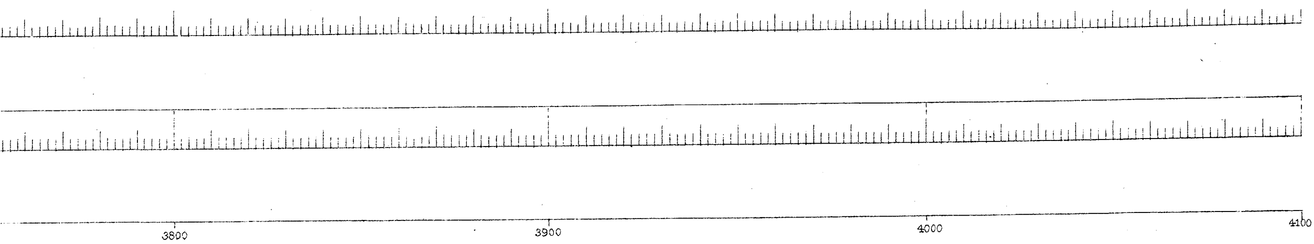

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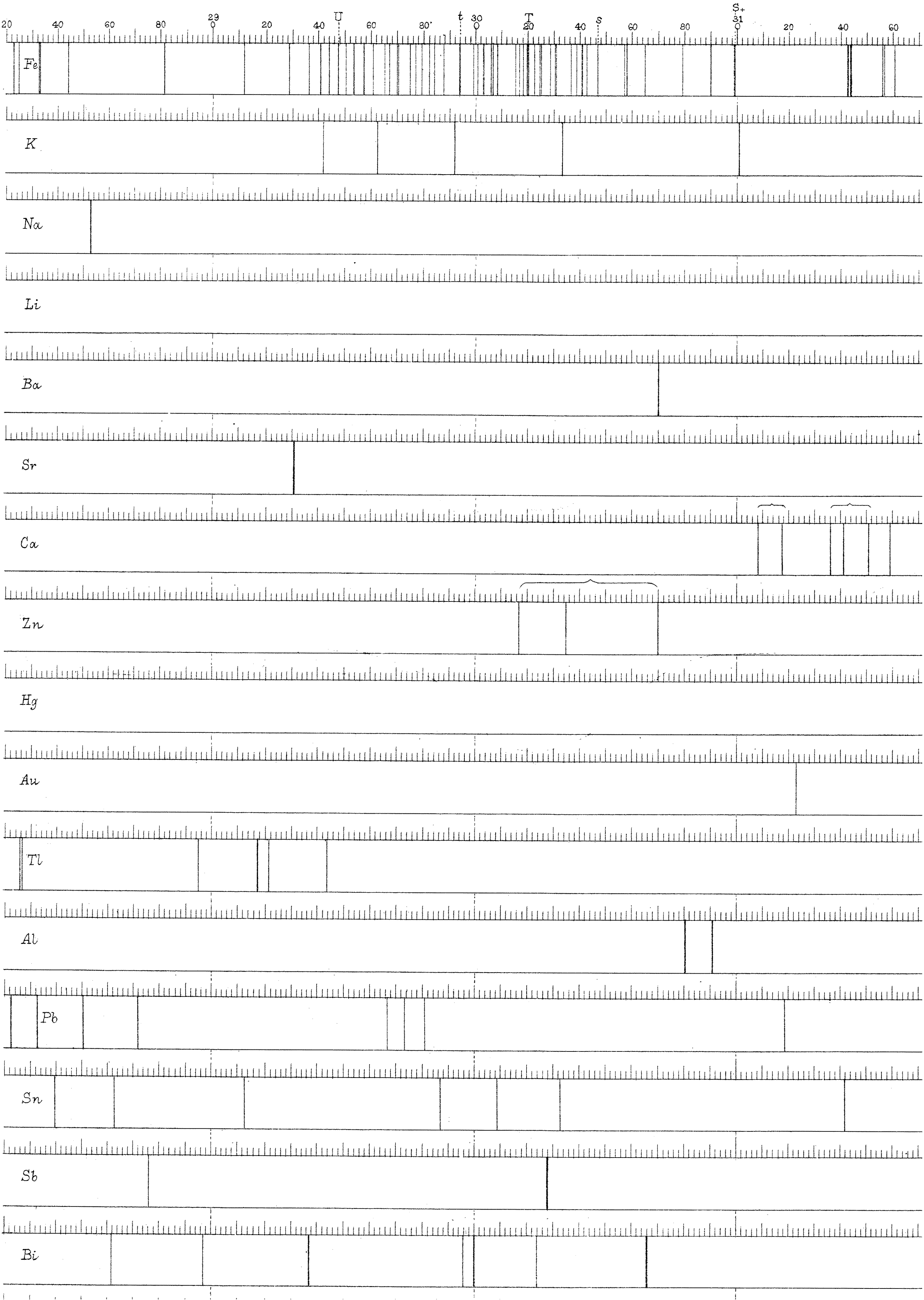

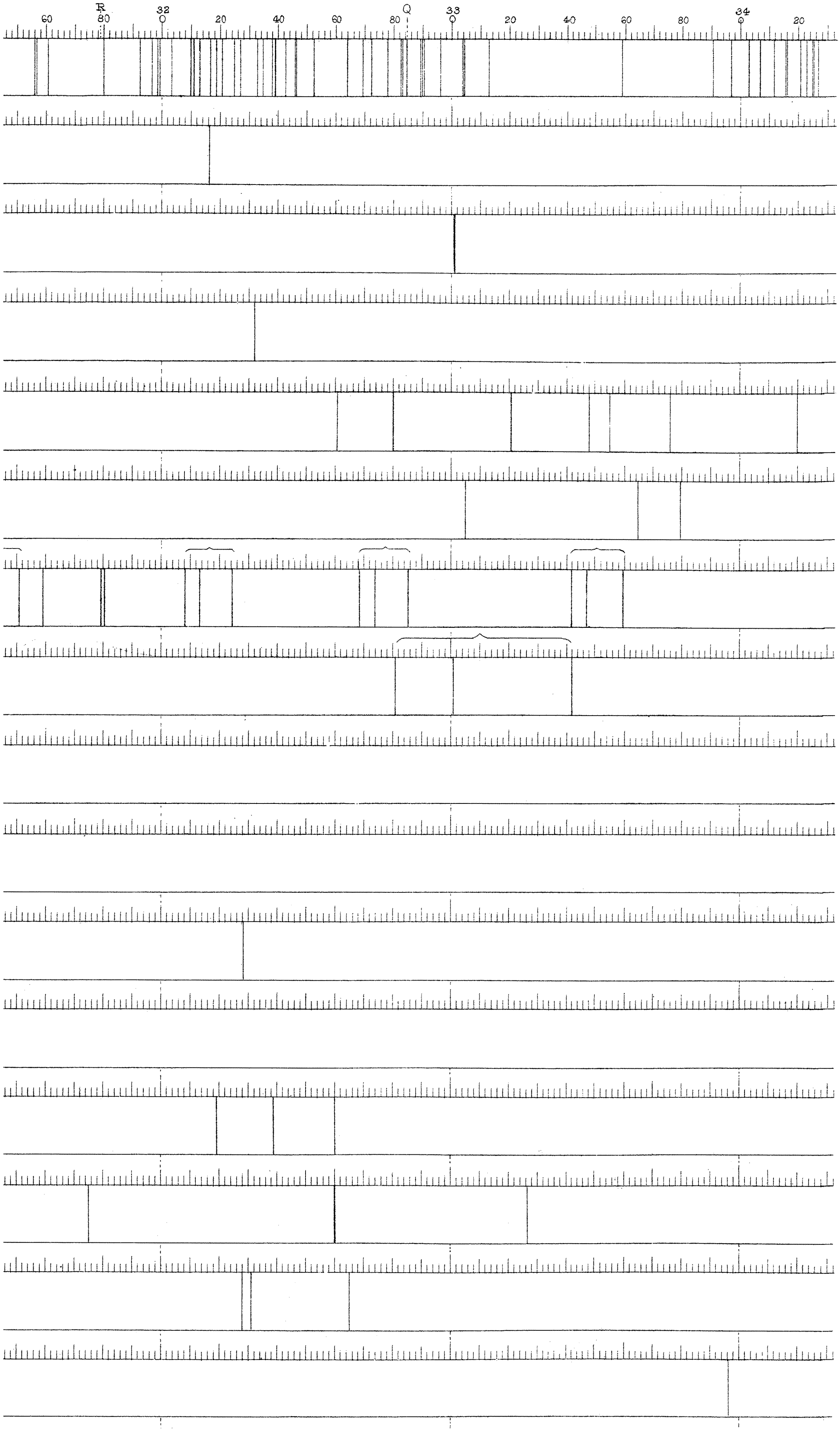
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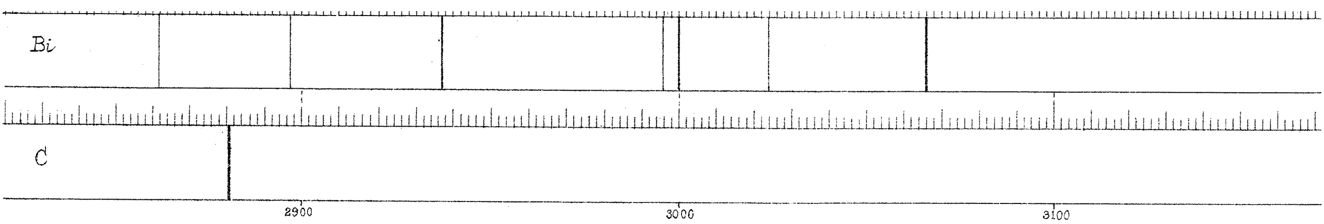
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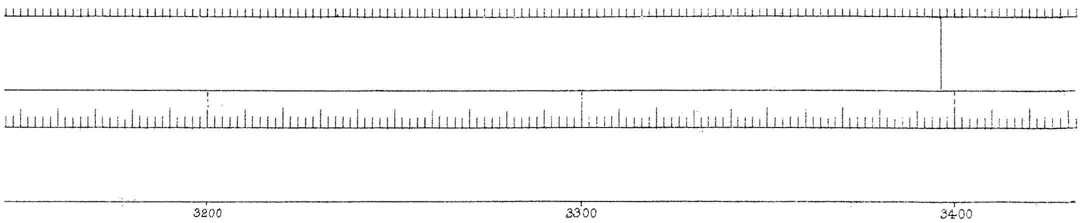

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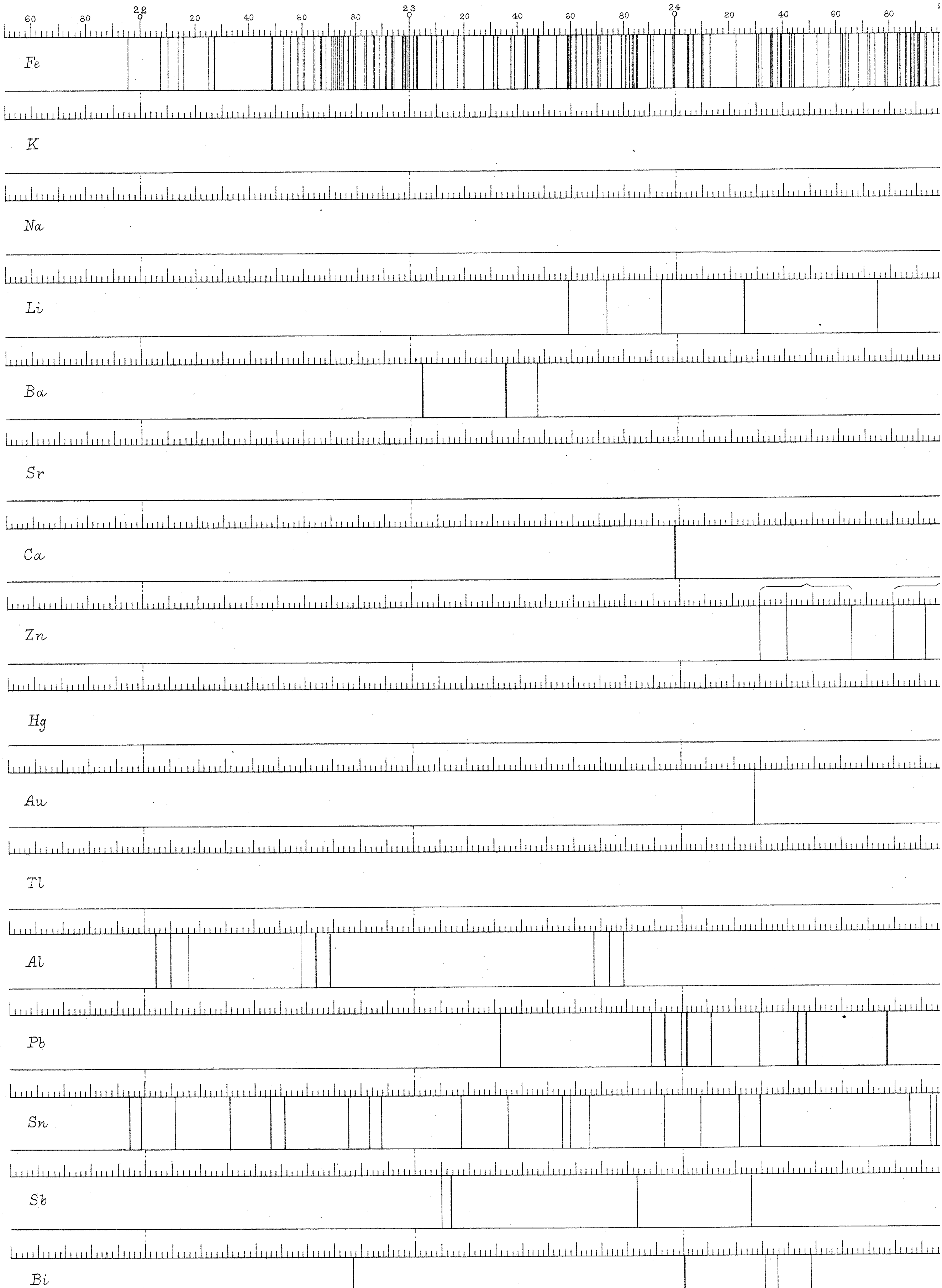

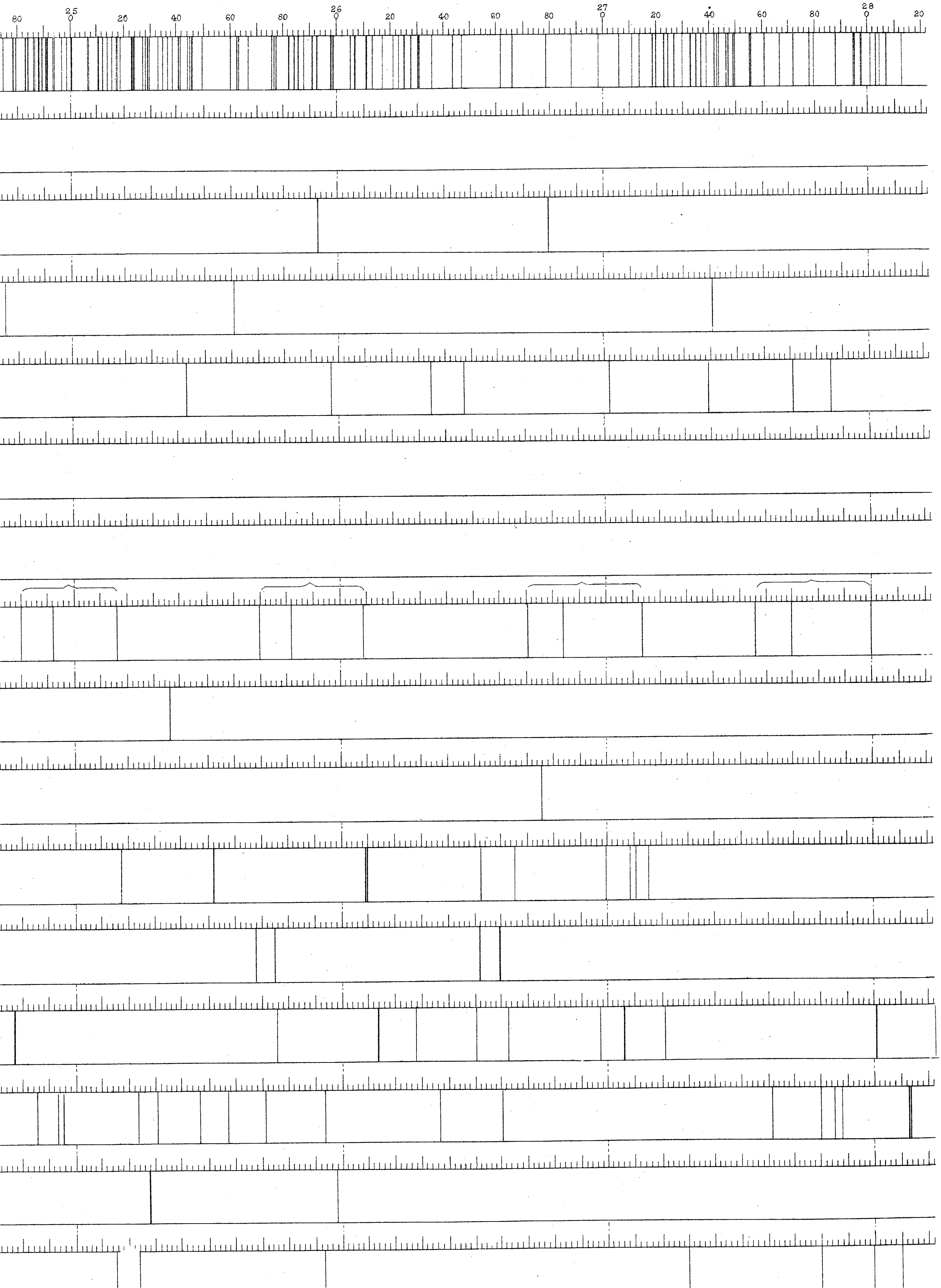
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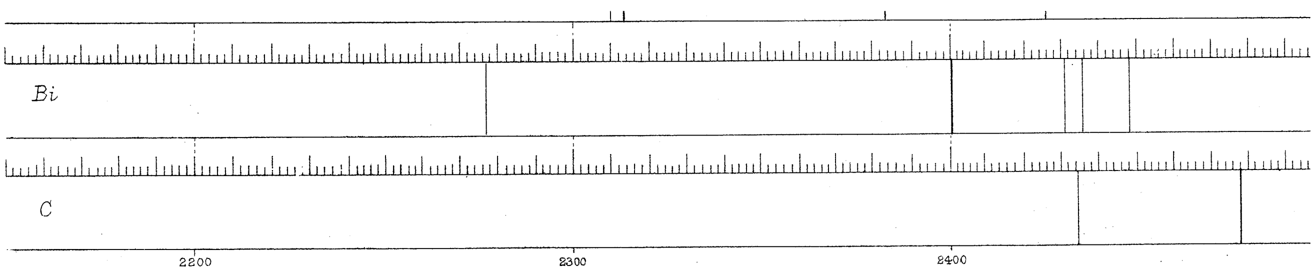
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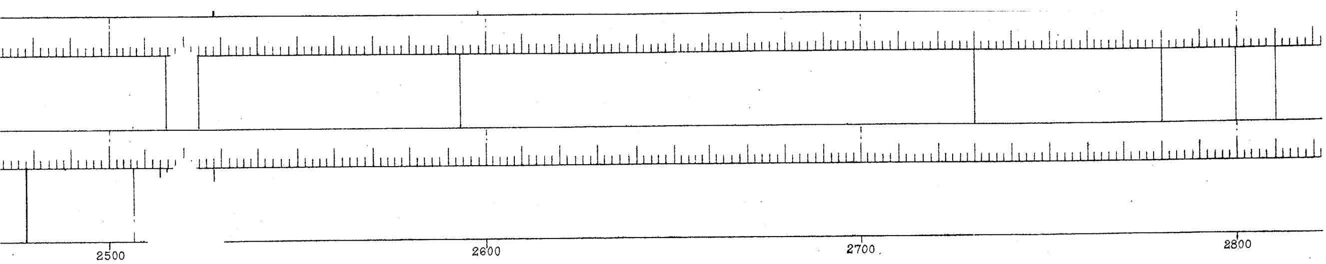

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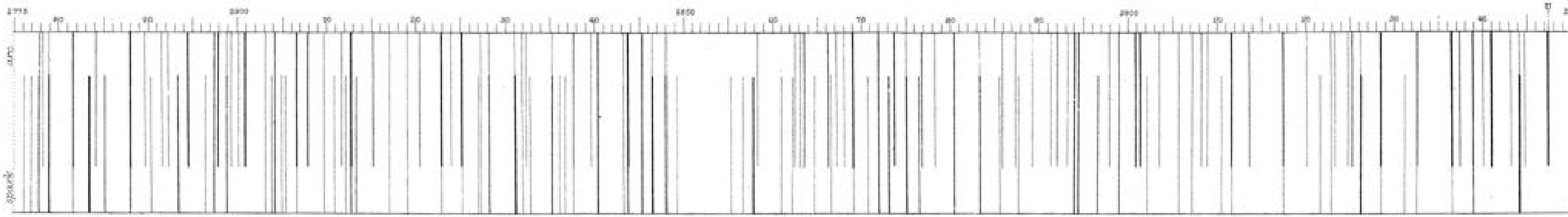
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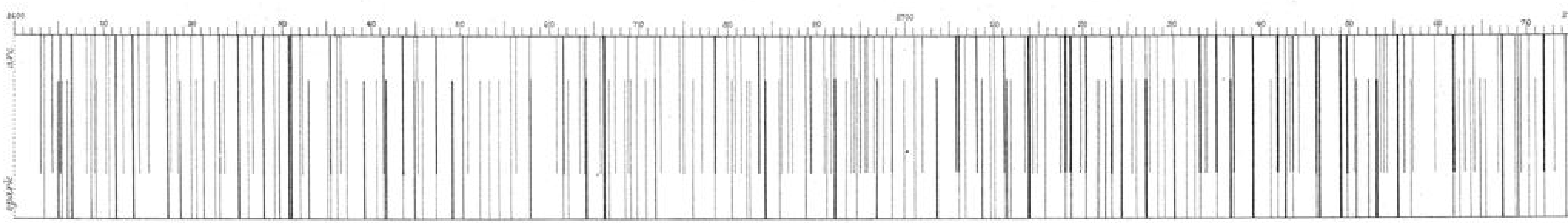
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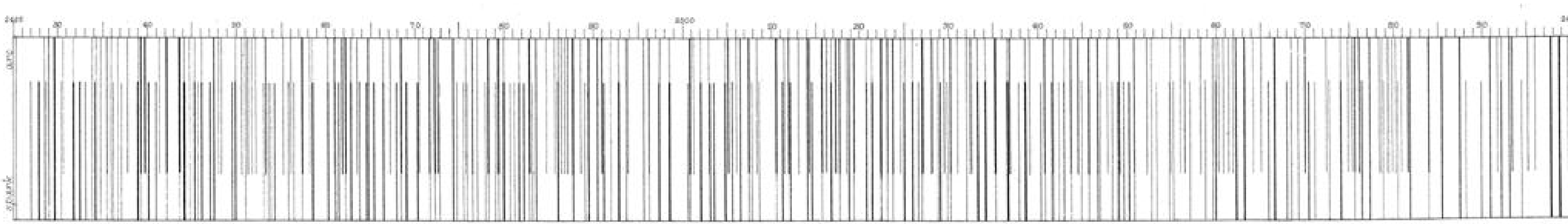
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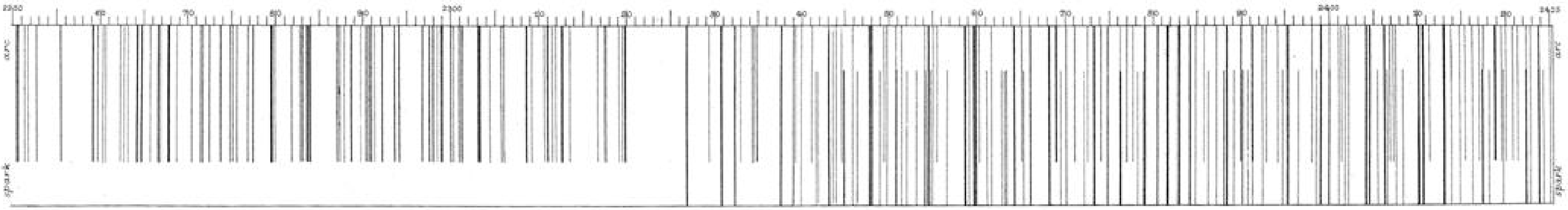

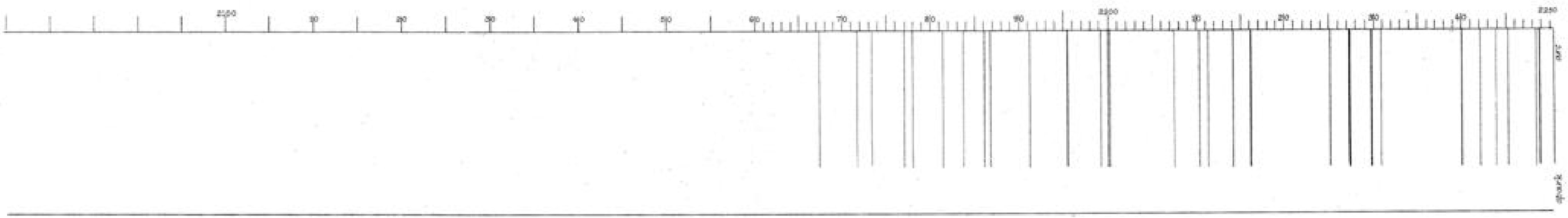

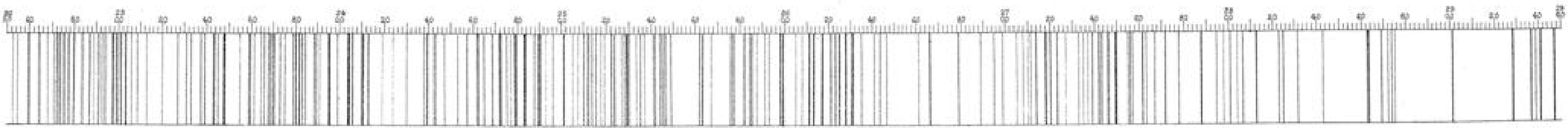

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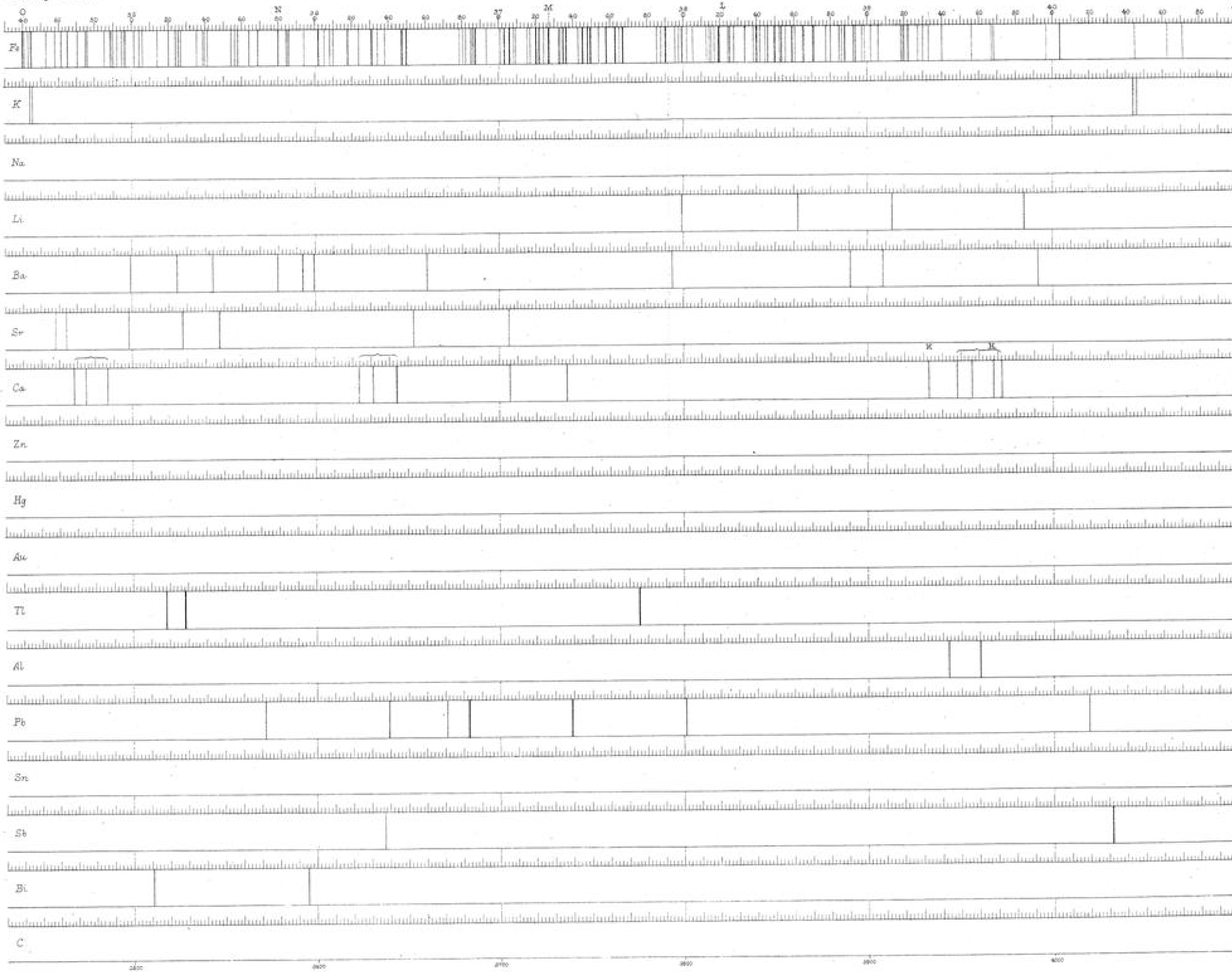

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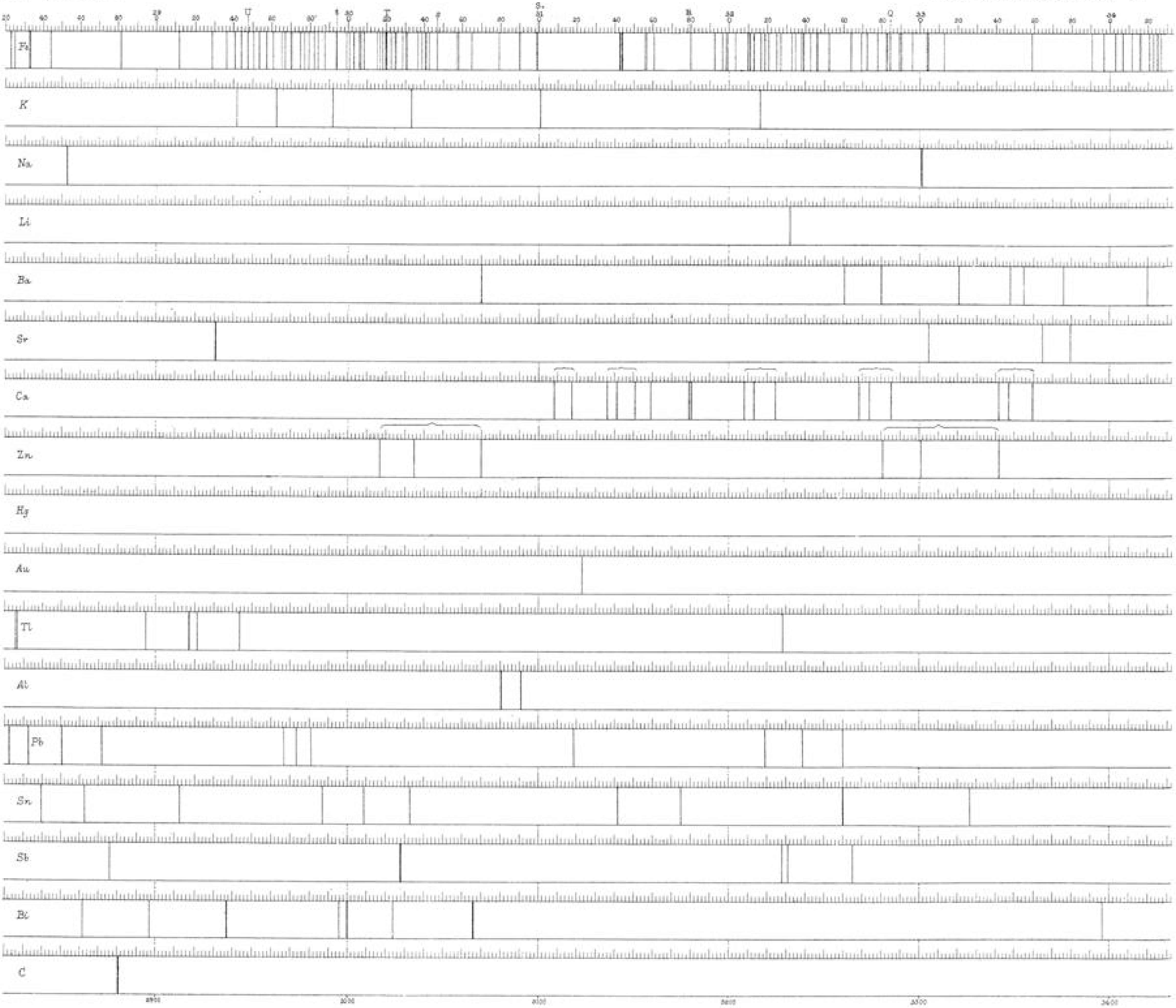
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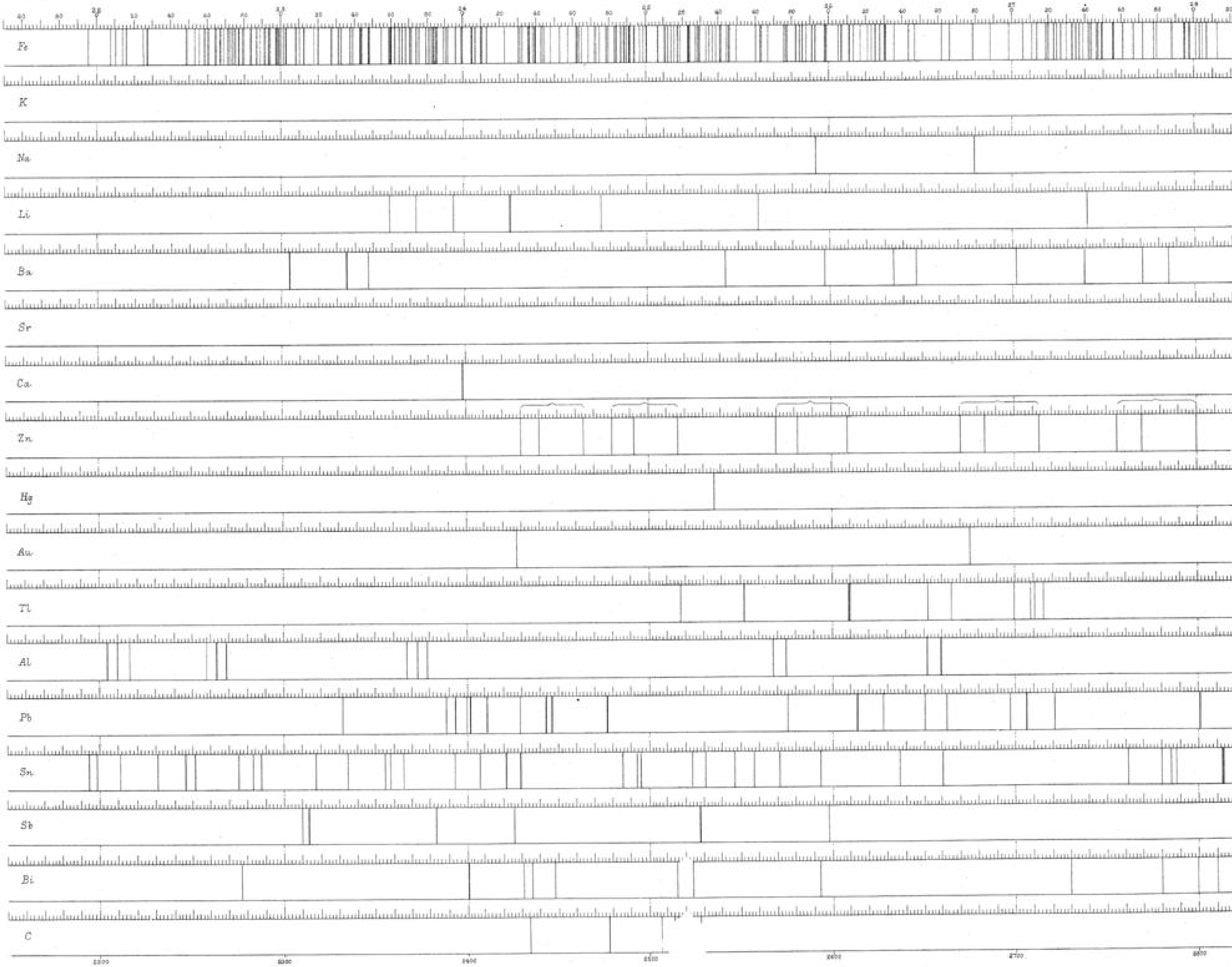

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