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VIII. *On the Ultra-Violet Spectra of the Elements.*—Part III. *Cobalt and Nickel.*

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[Plates 9–14.]

In our first communication to the Society on this subject we gave a reference map of the iron lines in the ultra-violet region, based on measurements of the wave-lengths of nearly a hundred of the principal lines. These measurements were made by means of a diffraction grating by Rutherfurd. Since that time we have obtained some of Rowland's fine gratings, having a much larger ruled surface, though a somewhat smaller number of lines to the inch, than the Rutherfurd grating. With larger gratings it was advantageous to use larger telescopes, and it was a matter of some interest to determine whether the improved appliances led to the same numerical values of the wave-lengths as before. In each case we determined the constant of the grating—that is, the distance between successive lines—by Ångström's scale. We had, for instance, measured the deviations by the Rutherfurd grating of several lines—namely, C, D, *b*, F, and H—for as many orders of spectra as we could on both sides of the collimator, and then calculated what must be the distance between the lines to produce these deviations, on the assumption that Ångström's wave-lengths of these lines were correct. We have since used the solar lines E, or the corresponding lines of the spectrum of the spark taken between iron terminals, for the purpose of gauging our gratings, because Ångström had bestowed the greatest pains in the measurement of the wave-lengths of these lines. Peirce and Bell have corrected Ångström's measures, but, for convenience in comparisons, we have retained the old scale. In order to make our numbers correspond to the new scale they must all be multiplied (according to Rowland) by 1·00016.

The first comparison of measurements with the different gratings was made with respect to the cadmium lines, which have frequently been used as lines of reference. Four pairs of photographs of the cadmium line No. 17 in Mascart's notation had given us the following wave-lengths :—

	2748·58 . .	at 4th order.
	2748·27 . .	„ „ „
	2748·20 . .	„ 5th „
	2748·16 . .	„ 6th „
Mean .	2748·30	

Six pairs taken with a ROWLAND grating and the same goniometer gave us—

	2748·43 . .	at 3rd order.
	2748·41 . .	„ 4th „
	2748·50 . .	„ 5th „
	2748·35 . .	„ 6th „
	2748·41 . .	„ 7th „
	2748·29 . .	„ 8th „
Mean .	2748·40	

BELL'S* value of the wave-length of the same line is 2748·45. The photographs were all taken with a collimating eyepiece. Considering that the cadmium lines, though strong, are very diffuse, so that there is room for considerable error in estimating the centre of the photographic image, and that an error of 0·013 mm. in measuring the distance between the two images of the line on the photograph would make an error of 1″ in the deviation, or very nearly ·03 in the value of the wave-length, the values above are fairly concordant. However, besides the difficulty of exact measurement arising from the ill-defined character of the cadmium lines, there is a source of error arising from the gratings themselves, and affecting both of them. It is that the two images of any given line, on the two sides of the normal to the grating, are not in focus at the same distance from the object-glass of the telescope. Hence, if the photographic plate is adjusted to the focus of a particular line when the grating is turned in one direction, it will not receive a sharp image of the same line when the grating is turned in the other direction.

With a collimating eyepiece it is comparatively easy to place the grating so that the normal to its plane may coincide with the axis of the collimator. Hence, fair measures of the wave-length of any line may be obtained from the deviation for that line, as measured on one side only of the normal. But, since every change of focus makes it necessary to take a fresh reading of the position of the grating when it is normal to the axis of the collimator, it is better, as a rule, because errors of reading thereby become of less consequence, to measure the angle between the two images, one on one side and the other on the other side of the normal. If this is done, the difficulty arising from difference of focus on the two sides must be faced, as any alterations of adjustment between the times of taking the pair of photographs would be wholly inadmissible.

* 'Amer. Journ. Sci.,' vol. 31, 1886, p. 429.

Again, it seldom happens that a grating gives the two spectra of the same order equally bright. With one of our gratings the spectra of the 3rd and 5th orders are bright on one side only of the normal, while those of the 4th and 6th orders are bright on the other side only. Where faint lines were in question, therefore, we have used spectra of different orders on the two sides, and computed the wave-length by the formula $(m + n)\lambda = 4a \sin \frac{1}{2}(\alpha + \beta) \cos \frac{1}{2}(\alpha - \beta)$; where m and n are the orders of the spectra employed, α and β the deviations of the ray from the normal. $(\alpha + \beta)$ is, of course, the angle directly measured; $(\alpha - \beta)$ has to be calculated from the reading of the instrument when the grating is normal to the axis of the collimator. As $\frac{1}{2}(\alpha - \beta)$ is always a small angle, any error in determining it will affect the value found for λ but little.

Measures of other cadmium lines gave the following results :—

No. of line.	RUTHERFURD grating.		ROWLAND grating.		BELL'S value of λ
	No. of pairs of photographs.	λ	No. of pairs of photographs.	λ	
18	1	2572·95	5	2572·75	2572·95
22	2	2329·67	5	2320·92	2321·14
23	2	2312·66	5	2312·75	2312·83
24	2	2264·91	4	2264·64	2264·88
..	2	2240·10	..	..	..
25	1	2194·06	$7\frac{1}{2}$	2194·28	2193·98

Previous measures of lines Nos. 24 and 25, by interpolation between the copper lines of which the wave-lengths had been determined by RUTHERFURD'S grating, had given the values of λ 2265·0 and 2194·2.

Other cadmium lines, measured by ROWLAND'S grating, gave the following results :—

No. of the line.	No. of pairs of photographs.	λ	BELL'S value of λ
9	3	{ 3612·15 3609·75	3611·75 3609·39
10	3	{ 3467·03 3465·61	3466·70 3465·22
11	5	3403·08	3402·68
12	5	{ 3260·46 3252·08 3249·83	3260·12 3251·77 3249·40

The wave-lengths of this last group of lines are all too large by about 0·35 as compared with BELL'S, and they seem to be affected by some common error, but whence it arises we do not know. Our measures of lines in the visible spectrum, where, of course, there are fewer sources of error, agree very closely with BELL'S. Thus our measures of the blue lines gave the figures for λ 5085·26, 4799·40, and 4677·59, and these, when multiplied by the factor 1·00016, come very close indeed to BELL'S numbers, which are 5086·09, 4800·15, and 4678·39. On the whole, we are inclined to think that a really good goniometer with a plane grating and a telescope of moderate dimensions, focal length 8 or 9 decimeters, will give extremely accurate wave-lengths, while the greater angular aperture of such a telescope gives it a considerable advantage in point of light over the concave grating used by BELL. The method of measuring wave-lengths by the coincidences of lines in spectra of different orders, for which a concave reflecting grating is admirably adapted, could not be easily applied to the ultra-violet spectra of cobalt and nickel, because the lines are so crowded that the overlapping of two or three spectra, all in focus together, would produce a complication which it would be nearly impossible to unravel, except by dispersing the spectra in a direction at right angles to the dispersion produced by the grating. The chromatic aberration of our quartz lenses is a positive advantage in dissipating the light of the spectra of those orders which are not under examimation.

For the determination of the cobalt and nickel lines specimens of those metals were prepared so far spectroscopically pure that the spark between fragments of the cobalt showed none of the characteristic strong lines of nickel, and the spark between pieces of the nickel showed none of the characteristic strong lines of cobalt. As the metals after reduction were fused with an oxyhydrogen blowpipe in lime crucibles, they were not free from all traces of other metals. For the arc lines much labour in the purification of the metals would have been wholly thrown away, because a variety of metals are present in the carbon electrodes as well as in the limestone used for crucibles. In the arc, therefore, we used samples sold as "pure," and identified the lines either by their coincidence with spark lines photographed at the same time through a part of the slit, or by their making their appearance, or being notably strengthened, on the introduction of the metal into the arc. The list of arc lines is much less complete than the list of spark lines, because weak lines in the arc are more easily overlooked in a photograph crowded with lines, and when noticed their origin is with difficulty identified. The wave-lengths of the spark and arc lines which were not measured directly by means of a grating were determined by interpolation from photographs of refraction spectra. In the highest region the copper lines were used as lines of reference in this interpolation. For the direct determination of the wave-lengths of the nickel lines about 170 photographs were taken, measured, and the results reduced; for the cobalt lines about 200. In many cases several lines could be measured on the same plate, but we have rarely been satisfied without getting two or more independent measures of the deviation for each line, and in many cases the measures have been made in more than one order of the spectra. Owing to difference in the strength of the spectra on the two sides of the normal to the grating, it sometimes happened that faint lines appeared in one of a pair of photographs, that is on one side of the normal, but not on the other. In such cases, when the reading of the circle for the normal position of the grating (which is liable to vary with every adjustment of focus) could be accurately determined by the help of stronger lines, which could be measured in both photographs, the wave-lengths of the faint lines have been calculated from the deviation as measured on one side of the normal. Such a measurement, though it gives a valuable result, is plainly not quite independent.

From the close chemical relationship between cobalt and nickel we should have expected that their spectra would closely resemble one another. In regard to the large number of lines which they exhibit, they certainly resemble each other, and resemble iron; and the resemblance goes a little further, inasmuch as the lines of all three spectra are much more crowded in certain regions than in others, and the crowded regions are approximately the same for all three. But, beyond such a general resemblance, we have been unable to trace any definite correspondence in the spectra. The number of lines of cobalt which according to our measurements have wave-lengths identical with those of nickel lines is small, but in a record of 580 lines of cobalt and 400 of nickel it would be surprising if there were not many close coincidences, and, in fact, we note forty-six cases where lines of cobalt do not appear to differ in wave-length from lines of nickel by more than a tenth of a tenth-metre. Now, if the cobalt lines were uniformly distributed over the whole region mapped and the nickel lines distributed at random amongst them, it would be an even chance that twenty-six nickel lines would not be more than a tenth of a tenth-metre distant from the nearest cobalt lines. A glance at the map will, however, show that the cobalt lines are by no means evenly distributed, and in the regions where they are most closely packed the nickel lines are also for the most part closely packed. Hence, the chance of merely accidental coincidences is very much greater than that above mentioned; and we find that in the region between the wave-lengths 2250 and 2550 the number of lines of the two metals, which, as measured, are not more than a tenth of a tenth-metre distant from one another is twenty-five, more than half the whole number of coincidences to that degree of approximation. On the whole we are unable to conclude that the coincidences are more than fortuitous. It should be observed that we have not yet had the opportunity of comparing the spectra of the two metals photographed on the same plate with high dispersion. On many of our plates the iron spark has been photographed simultaneously with the spectrum of another metal, and we have noted on the table of wave-lengths the cases in which these photographs show an unresolved coincidence between an iron line and a cobalt or nickel line. These photographs, however, have all been taken with a prismatic spectroscope, and it is probable that a higher dispersion might resolve some of these coincidences.

TABLE of Cobalt lines.

In the first two columns are given the intensities, 1 to 6, of the lines as observed in the spark and arc respectively, 1 being the most intense. In the third column are recorded the wave-lengths. A figure in the fourth column indicates that the wave-length against which it is placed was independently measured by means of a grating, and at the same time records the number of separate determinations combined in the given result.

Intensity.		λ		Remarks.
Spark.	Arc.			
6	. .	2190·2		The wave-lengths of the lines in this region were obtained by interpolation between the copper lines photographed at the same time through a part of the slit
6	. .	2191·9		
6	. .	2193·1		
6	. .	2198·2		
6	. .	2205·7		
6	. .	2214·1		
6	. .	2215·9		
6	. .	2219·6		
6	. .	2229·5		
6	. .	2231·5		
6	. .	2234·4		
3	. .	2244·8		
6	. .	2253·2		
2	. .	2256·4		
2	. .	2259·7		
2	. .	2266·2	. .	A weak Ni line
6	. .	2270·5		
6	. .	2272·0		
5	. .	2273·3	. .	Also a Ni line
6	6	2274·2	. .	A stronger Ni line
6	. .	2275·1		
6	. .	2275·9		
6	. .	2278·1		
5	. .	2280·1		
4	. .	2281·5		
6	. .	2281·9		
5	. .	2283·1		
2*d*	2	2285·7	1	
6	5	2287·8		
6	6	2289·9		
6	6	2290·9		
3	4	2291·5	1	
3	2	2293·0		
5	4	2295·5		
5	5	2296·9		
6	6	2298·3		
4	6	2299·3		
5	5	2300·3		
5	4	2300·8		
6	. .	2303·8		
6	. .	2305·6	. .	Also a Ni line
6	. .	2306·4		
1*d*	2	2307·4	2	

TABLE of Cobalt lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
6	6	2310·4		
1	3	2311·1	2	Also a Ni line
5	5	2312·1		
4	..	2313·1		
2	3	2313·5	2	Also a Ni line
2	5	2314·5	2	
6	4	2315·5	..	Also a Ni line
3	5	2316·8	..	Also a Ni line
6	..	2318·2		
6	4	2319·6		
6	5	2321·0	..	Also a Ni line
3	4	2324·0	2	Also a Ni line
3	5	2325·9	2	
3	4	2326·1	1	Also a Ni line
5	..	2327·3		
6	6	2328·7		
3	5	2330·0	1	Also a Ni line
6	6	2333·7		
3	4	2335·9	1	
5	..	2336·6	..	Also a Ni line
2	4	2337·6	1	
6	4	2338·4		
5	4	2338·8		
2	..	2340·8	1	Also a Ni line
3	..	2344·0	1	Also a Fe line
4	..	2344·3		
5	5	2345·2		
4	6	2346·2	..	Also a Ni line
6	5	2346·7		
3	5	2347·0	1	
5	..	2347·4		
6	..	2348·1		
5	5	2350·6	..	Also a Ni line and a Fe line
6	5	2351·5		
6	3	2352·1	1	
1	3	2353·0	2	
4	4	2357·7	1	
4	6	2360·0		
5	6	2360·2	2	
4	..	2360·3		
6	6	2360·8		
6	6	2361·2		
1	3	2363·3	2	
6	5	2366·6		
5	4	2370·1		
3	4	2371·5	2	
5	4	2371·3		
5	5	2372·6		
4	6	2374·8	2	Also a Fe line
1	2	2378·1	3	
6	6	2380·3		
2	4	2381·3	2	
5	..	2381·7		Also a Ni line

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
2	4	2382·9	2	
2	4	2385·9	2	
3	6	2386·1	1	
5	4	2388·3	2	A rather close double, very near a Fe line
1	6	2388·4		
3	4	2389·1		
6	4	2391·5		
4	4	2392·1	. .	A weaker Ni line
4	6	2393·4		
4	4	2395·1		
1	5	2396·9	3	
4	5	2397·8	2	
6 }	2 {	2401·3	1	
6 }		2401·6	. .	Also a Ni line
6	6	2402·4		
6	6	2403·3		
3	4	2403·8	3	
4	6	2404·0		
4	6	2405·1	1	
6	. .	2406·9		
3	1*d*	2407·1	3	
3	. .	2407·8	2	
3	4	2408·3	2	
2	1	2411·2	2	
6	3	2412·2	2	Also a Ni line and an air line
3	4	2413·7	3	
5	2	2414·1		
5	2	2414·8	1	
3	. .	2415·5		
4	. .	2415·7	2	
3	5	2416·5	2	
3	3	2417·2	2	
3	4	2418·1	2	
1	6	2420·3	3	
6	6	2421·6		
6	4	2422·1		
3	6	2423·2	2	
4	1*d*	2424·5	2	
5	6	2425·7	2	
3	. .	2427·8	2	
5	5	2429·6	2	
6	. .	2430·0		
1	1	2432·0	4	
5	2	2434·6		Close to a Si line
6	5	2435·8		
6	2 {	2436·2		
3		2436·5	3	
6*d*	. .	2437·9		
5	3	2438·5		
6*d*	. .	2439·7		
6	4	2440·6		
5	4	2441·2		
2	. .	2442·0	3	

TABLE of Cobalt lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
3	5	2443·3	2	
3	6	2445·6	3	
2	5	2447·3	2	Also a Fe line
4	..	2448·7	2	
2	..	2449·4	3	
6	6	2452·0		
6	..	2452·7		
6	5	2453·3		
6	..	2453·6		
6	2	2455·7		
3	..	2459·0	1	
6	3	2460·3		
6	..	2460·8		
1	4	2463·7	2	
2	..	2466·5	2	
6	6	2469·0		
6	3	2469·7		
6	2	2472·5		
6*d*	6	2473·5		
6*d*	..	2474·9		
6	..	2476·0		
6	3	2476·2		
6	..	2476·9		
4	..	2477·1	2	Also a Fe line
4	..	2477·8		
5	..	2478·6	..	Close to a carbon line
6	4	2483·2		
6	..	2484·1		
6	..	2484·4		
3	..	2484·8	1	
3	..	2485·9	3	Also a Fe line
6	..	2486·7		
6	..	2486·9		
3	3	2489·8	1	
6	3	2490·4		
6	5	2494·4		
6	4	2495·1		
6	2	2496·3		
3	3	2497·1	1	
4	..	2498·2	1	
5	3	2500·2		
5*d*	6	2501·7		
6	3	2504·1		
1	1	2505·8	3	
4	4	2507·5	1	
6	..	2509·4		
1	1	2510·5	2	Also a Ni line
6	..	2511·4		
6	6	2511·7		
4	..	2516·9		
5	2	2517·3		
1	..	2519·3	2	
5	1	2520·7	1	

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
4	. .	2522·5	1	Close to an air line
6	1	2524·2	1	Close to a Li line
2	. .	2524·5	1	
2	2	2528·1	1	Also a Si line
3	3	2529·6	1	
6	1	2531·7		
2	. .	2533·4	1	Close to a Fe line
5	4	2535·5	1	
6	4	2536·1		
5	6	2537·0		
3	2	2540·2	1	
2		2541·5	1	
6	3	2543·9		
6		2544·2		
5	4	2544·6		
6	3	2545·7		
2	. .	2546·3	1	
6	4	2548·9		
6*d*	4	2549·7	. .	Also a Fe line
4	. .	2550·1	. .	Also a Fe line
4	. .	2552·2		
6	4	2552·7	. .	Also a Ni line
6	4	2553·1		
3	. .	2556·3	1	
4	4	2556·9	1	
2	6	2558·9	1	
3	6	2559·6	1	
6	1	2561·7		
1	6	2563·6	1	
6	. .	2565·0		
6	3	2567·0		
3	. .	2569·3	1	
6	4	2571·9		
6	4	2573·1		
3	5	2574·4	1	Also an Al line
1	5	2579·8	1	Also a Ni line and close to an air line
3	6	2581·7	1	
5	. .	2582·6	1	
6	5	2584·8		
2	6	2586·8	. .	Also a Ni line
6	6	2592·9		
6	6	2598·8	. .	Also a Fe line, or close to it, and close to an air line
6	5	2600·3		
5	5	2603·9		
4	4	2605·2		
6	5	2605·3		
4	. .	2613·0		
3	6	2613·8		
4	2	2618·5		
4	6	2619·3		
6*d*	4	2621·7		
6*d*	6	2626·6		
6	3	2627·3		

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
6*d*	..	2628·4	..	A Ni line, doubtful Co line
3	6	2631·9		
5	..	2634·5		
6*d*	6	2642·7		
6	6	2644·4		
5	3	2646·1		
2	1	2648·4		
3	..	2653·3		
2	6	2662·7	1	
5	6	2669·7	1	
6	..	2670·1	..	Also a Ni line
3*d*	4	2675·4		
5	..	2677·4		
6	4	2679·0		
5	..	2679·8		
6	..	2681·5		
3*d*	..	2684·0	1	Also a Ni line
5	..	2689·2	1	
5	..	2692·5	1	
2	6	2694·1	2	
6	3	2695·3	1	
6	..	2695·9		
6	..	2696·0		
6	..	2696·4	1	
4	..	2701·9	1	
4*d*	..	2706·2	1	Also a Fe line
6*d*	..	2706·9	1	Also a Fe line
5*d*	..	2707·4	1	
6	6	2708·6	1	Also a Fe line
3	..	2713·9	3	Very close to a Fe line
6	..	2714·5		
5	3	2715·3		
4	..	2720·6	1	Very close to a Fe line
4*d*	..	2727·5		
4*d*	..	2728·8		
6	6	2730·7		
6	..	2732·6		
5*d*	..	2734·3		
6	..	2738·6		
5	5	2744·7		
6	6	2757·1		
6	5	2761·0	1	
5	4	2763·9		
5	4	2766·0		
5	..	2766·5	1	
4	6	2768·6	1	
5*d*	6	2774·8	..	Also a diffuse line in the Ni spark
2	..	2775·7	1	
6	6	2778·5		
5*d*	..	2785·2		
5*d*	..	2785·7		
5*d*	..	2786·9	1	
6	..	2789·1	..	Also a Fe line

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
3	..	2793·4		
6	..	2795·8		
6	..	2796·3		
6	..	2796·6		
6	6	2798·4		
5*d*	..	2801·7	1	
6	5	2803·3	..	Also a Fe line
4	..	2806·7	2	Also a Fe line
3	..	2810·3	4	
4	3	2815·2	1	
6*d*	..	2815·8		
6	6	2818·3		
6	6	2819·4		
6*d*	5	2821·1		
5*d*	..	2822·7		
6	..	2823·2	1	
2	2	2824·5	5	
3	..	2834·3	1	
6	6	2836·7		
6	..	2845·2		
5*d*	..	2847·9	..	Also a Fe line
6	5	2849·8		
6	5	2862·2		
6	..	2865·1	..	Also a Ni arc line
2	..	2870·4	1	Very close to a Fe line
6*d*	..	2879·9		
6	3	2881·3	1	
6*d*	..	2883·1		
5	4	2886·0		
2	6	2890·0		
5*d*	..	2897·5		
6	3	2899·3		
6	5	2906·5		
3*d*	..	2918·1		
6	6	2927·2		
6	6	2929·0		
2*d*	..	2930·0		
2*d*	2	2942·5	1	
1*d*	..	2954·1	1	
6*d*	..	2971·2		
6*d*	6	2983·3		
3	3	2986·5		
3	3	2989·1		
6	..	2994·7		
6	5	3000·1		
6*d*	6	3008·5		
6	5	3010·3		
4	4	3013·2		
6	6	3015·2		
3	..	3017·0	..	Very close to a Fe line
2 {	5	3033·8		
	5	3034·0		
6	5	3042·2		

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
3	3	3043·6		
3	3	3048·6		
4	3	3050·6	..	Very close to a Ni line
6	6	3059·6		
2	3	3061·4		
6	5	3063·0		
6	4	3064·0		
2	6	3071·8		
	2	3072·0		
6	6	3073·4		
6	6	3078·9		
3	3	3082·1		
2	2	3086·3		
4	4	3089·0		
4	3	3097·6		
6	..	3101·8		
5	5	3103·3		
6	6	3109·0		
6	6	3109·5		
5	5	3113·0		
2	2	3121·1	1	
6	6	3126·7		
4	6	3130·4	1	
3	2	3136·8	1	
3	3	3139·5	1	
3	3	3146·6	1	
5	4	3148·9		
6	6	3152·3		
2	3	3154·2	1	
3	3	3158·2	1	
5	5	3159·2		
6	6	3161·3		
6	6	3164·3		
5	5	3169·5		
6	4	3174·8		
4	5	3176·6	1	Out of focus in photograph with grating
5	5	3181·7		
5	5	3188·0		
6	6	3210·1		
5	4	3218·7		
6	6	3226·5		
5	4	3232·4	1	
5	5	3235·2		
5	4	3236·7	1	
4	5	3243·4	1	Also a Fe line
3	..	3246·7	1	Also a Fe line
6	5	3249·6		
4	4	3253·7	1	
4	5	3260·1	1	
6	5	3261·7		
6	..	3262·7		
5*d*	5	3264·4		
5	6	3271·3		

TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
6	6	3276·0		
6	4	3277·2		
5	6	3278·5		
2	3	3282·9	1	
6	. .	3284·2		
5	5	3286·6		
6	. .	3294·2	1	
6	6	3303·2		
6	6	3306·5	1	
6	6	3308·2		
5	. .	3309·1		
5	5	3311·7	1	Also a Ni line
4	5	3313·6	4	
3	4	3319·0	1	
4	4	3321·7	3	Also a Ni line
5	5	3324·8	3	
5	5	3326·4	3	
6	6	3329·0	1	
2	1	3333·6	4	
5	5	3339·3	2	
6	5	3340·2	1	
6		3340·8	2	
5	5	3342·2	2	
5	5	3346·4	1	
5	5	3347·7	1	
6	5	3348·9	1	
4	. .	3352·3	4	
2	1	3353·9	4	
6	3	3360·8	1	Also a Ni line
6	6	3362·3		
3	1	3366·6	5	
4	4	3370·4	4	
6	5*d*	3376·6	1	
5	6	3378·0	2	
6	1	3380·0	2	Also a Ni line
4	2	3384·7	3	
6	. .	3387·1	3	
3	1	3387·6	5	
6	1	3394·2	1	
3	1	3394·8	5	
2	1	3404·5	4	Also a Ni line and in OH flame with $CoCl_2$
6	. .	3406·1		
3	1	3408·6	3	In OH flame with $CoCl_2$
2	1	3411·7	3	In OH flame with $CoCl_2$
3		3412·0	3	
. .	2	3414·2	3	
6	. .	3415·2	3	
4	2	3416·5	3	In OH flame with $CoCl_2$
4*d*	3	3423·2	3	Also a Ni line
4	2	3430·9	3	In OH flame with $CoCl_2$
5		3431·3		
3	1	3432·4	4	In OH flame with $CoCl_2$
3		3432·9	1	Also a Ni line

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TABLE of Cobalt lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
5d	4	3436·8	..	Also a Ni line
..	6	3438·2		
6	3	3442·3	3	
3	3	3443·0	3	In OH flame with $CoCl_2$
4	3	3445·7	2	Also a Ni line and in OH flame with $CoCl_2$
3	1	3448·6	3	In OH flame with $CoCl_2$
5		3448·9	2	
2	2	3452·9	3	Also a Ni line and in OH flame with $CoCl_2$
4	3	3454·6	2	
5	4	3460·6	2	
2	2	3462·2	3	In OH flame with $CoCl_2$
2	1	3465·2	5	Also a Ni line and in OH flame with $CoCl_2$ and a Fe line
1	1	3473·4	5	In OH flame with $CoCl_2$
6	2	3476·0	1	
6	5	3478·0		
3	1	3482·7	2	In OH flame with $CoCl_2$
4	4	3484·7	2	
1	1	3488·8	5	In OH flame with $CoCl_2$
5	4	3490·6	2	
3	1	3495·1	4	In OH flame with $CoCl_2$
5	3	3496·0	3	
4		3501·0	2	
1	1	3501·6	3	In OH flame with $CoCl_2$
5		3502·0	2	
6	..	3503·4		
1	2	3505·6	3	In OH flame with $CoCl_2$
4	3	3509·3	5	In OH flame with $CoCl_2$
6		3509·7	4	Also a Ni line
4	3	3512·0	3	In OH flame with $CoCl_2$
3	2	3517·7	5	
5	3	3519·5	2	
3	2	3520·9	4	Also a Fe line
3	3	3522·9	4	In OH flame with $CoCl_2$
4	3	3526·3	4	
6	4	3528·4	3	In OH flame with $CoCl_2$
3	1	3529·3	4	Also a Ni line
4	3	3532·8	4	In OH flame with $CoCl_2$ and a Fe line
4	5	3542·8	3	
6	6	3544·7	1	
6	6	3548·0		
4	3	3550·1	3	
6	6	3552·4	1	
6	..	3562·3		
2	3	3560·5	3	In OH flame with $CoCl_2$
3	1	3564·5	2	In OH flame with $CoCl_2$ and close to a Fe line
1	1	3568·9	3	In OH flame with $CoCl_2$
1	1	3574·5	2	In OH flame with $CoCl_2$
		3574·9	2	
6	5	3577·4	1	
3	2	3584·7	3	Also a Fe line
1	2	3586·7	3	

TABLE of Cobalt lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
3	1	3594·4	3	Observed in OH flame with $CoCl_2$
3	1	3601·6	3	Observed in OH flame with $CoCl_2$ and close to a Ni line
3	2	3605·0	4	Also a Fe line
6	6	3611·3	4	
6	6	3614·8		
3	1	3627·3	4	Observed in OH flame with $CoCl_2$
6	6	3632·2	4	
4	6	3634·2	2	
6	6	3636·1	1	
6	5	3638·9	3	
6	6	3641·1	1	
5	5	3642·7	3	
6	. .	3648·8	3	
6	. .	3654·0	1	
6	5	3656·1	1	
3	4*d*	3661·6	3	
6	. .	3680·8	3	
3	2	3682·5	3	
6	6	3690·2	1	
3	3	3692·4	1	
		3692·8	3	
3	6	3701·7	4	
2	1	3703·5	6	Observed in OH flame with $CoCl_2$
6	. .	3711·6		
5	5	3729·8	4	
4	5	3731·8	4	
6	5	3732·8	2	
6	. .	3735·2	2	
1	. .	3745·8	2	Observed in OH flame with $CoCl_2$
6	. .	3753·9	2	Arc lines obscured in this region by bands of cyanogen
6	. .	3769·7		
6	5	3774·0		
6	5	3777·0		
6	5	3807·3		
6	. .	3815·1	2	A Fe line here
6	. .	3815·7	2	
6	. .	3830·3		
2	4	3841·4	7	Observed in OH flame with $CoCl_2$
1	2	3844·8	9	Observed in OH flame with $CoCl_2$
4	. .	3860·5	5	Arc obscured by bands of cyanogen
2	1	3872·4	4	Observed in OH flame with $CoCl_2$
3		3873·2	5	
6	5	3876·1	4	
3	1	3881·0	5	
6	. .	3884·0		
1	1	3893·4	4	Observed in OH flame with $CoCl_2$
5	. .	3894·3	2	
6	4	3905·2		
6	4	3909·0	. .	Observed in OH flame with $CoCl_2$
6	6	3916·2		
3	5	3935·5	1	Observed in OH flame with $CoCl_2$
6	3	3940·9	1	Observed in OH flame with $CoCl_2$

TABLE of Cobalt lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
6	6	3944·9	1	
6	6	3952·4	1	
6	6	3955·7	1	
6	4	3957·7	1	
6	..	3968·8	1	
..	5	3974·1		
2	2	3978·7	..	Observed in OH flame with $CoCl_2$
..	6	3987·1		
..	5	3990·2		
..	5	3991·4		
1	2	3994·7	3	In OH flame with $CoCl_2$
6	1	3997·3	3	

TABLE of Nickel lines.

In the first two columns are given the intensities, 1 to 6, of the lines as observed in the spark and arc respectively, 1 being the most intense. In the third column are recorded the wave-lengths. A figure in the fourth column indicates that the wave-length against which it is placed was directly measured by means of a grating, and the figure records the number of separate determinations combined in the given result.

Intensity.		λ		Remarks.
Spark.	Arc.			
4	3	2173·8		
4	3	2174·4		
5	..	2176·0	1	
5	..	2176·7		
6	..	2179·4		
4	..	2179·9		
6	3	2182·8		
3	3	2184·2		
3	6	2185·0		
5	6	2188·2	1	
6	4	2190·0		
6	4	2190·6		
6	..	2193·2		
6*d*	3	2197·2		
6*d*	..	2198·0		
5	4	2198·4		
2	4	2200·8	1	
6*d*	..	2203·0		

TABLE of Nickel lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
3*d*	3	2205·2		
2	2	2206·1	1	
2*d*	3	2209·8	1	
4	4	2210·5	..	Also a Fe line
6	5	2211·4	..	Also a Fe line
4	5	2212·5	1	
2	1	2215·8	2	A weak line in Co
3	5	2216·0		
5	5	2217·4	2	
6	..	2219·0		
3	6	2219·8	2	
5	..	2220·6		
6	5	2221·3		
6	..	2221·7		
3	2	2222·3	2	
3	..	2223·8	1	
3	2	2224·3	2	
6	..	2225·3	..	Also a Fe line
3	3	2225·8	2	
6	..	2226·7		
6	2	2227·2	..	Also a Fe line
4*d*	3	2229·6	..	A weak line in Co; also a Fe line
6	..	2231·2		
5	..	2233·5	} 1	The mean of this pair was measured by the grating
6	..	2235·5		
6*d*	..	2237·6		
6*d*	..	2238·2		
6*d*	..	2239·8		
6	..	2241·2		
6	5	2242·2	1	A weak line in Fe
6*d*	2	2244·4		
6*d*	..	2245·9	1	
5	..	2246·6	1	
6	..	2247·4		
6	4	2248·8	..	Also a Fe line
6	..	2249·2		
6	..	2250·2		
6	6	2250·5	..	Also a Fe line
6	6	2251·1	..	Also a Fe line
6	4	2251·4		
6	..	2252·6		
1*d*	2	2253·5	2	
6	..	2253·9		
3	3	2254·7	1	
3	5	2255·7	1	
4	3	2257·6		
5	..	2258·9		
6	3	2259·4		
6	..	2260·3	..	Also a Fe line
6	4	2261·1		
6	6	2262·6		
..	4	2263·1	..	A weak Fe line; ? if Ni
2	1	2264·1	2	Also a Fe line

TABLE of Nickel lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
5	. .	2264·8	. .	Also a Fe line.
6	5	2266·1	. .	A stronger line in Co
6	3	2269·1	1	
1*d*	1	2269·9	2	
6	. .	2270·3		
6	5	2271·1		
6	. .	2272·3		
6	6	2273·2	. .	Also a Co line
3	3	2274·1	. .	A weak Co line
4	5	2275·0	. .	A weak Co line and a Fe line
5	4	2275·7	1	Also a Fe line
. .	5	2276·3		
3	6	2277·0	2	
3	4	2277·8		
2*d*	3	2278·4	1	
6	1	2279·2		
6*d*	. .	2280·6		
6	6	2283·7		
6	. .	2284·8		
2	3	2286·8	1	
2	6	2287·4	1	
4	4	2289·6		
6	. .	2290·7		
6	6	2292·7		
6	. .	2295·3	1	
2	. .	2296·2	1	
3	. .	2296·7 }	2	{ The mean of this pair was measured by the grating
3	6	2297·1 }		
3*d*	6	2298·0	4	
3	. .	2299·2	4	
3	. .	2299·8	4	
6	. .	2301·5	1	
2	. .	2302·0	4	
2	. .	2302·5	5	
3	4	2303·3	2	
3	. .	2304·8	2	
6	. .	2305·7	. .	Also a Co line
3	6	2308·1	2	
5*d*	3	2310·6	1	
6	. .	2311·2	. .	Also a Co line
4	3	2311·8	3	
3	. .	2312·5	3	
6	3	2313·4		
5	3	2313·6	1	Also a Co line and a Fe line
1*d*	3	2315·6	3	Also a Co line
6	3	2316·8	. .	Also a Co line
3	. .	2318·0	2	
3	3	2319·3	3	
4	2	2321·0	2	Also a Co line
6	5	2321·6		
6	3	2322·3		
6*d*	. .	2323·3		
6*d*	. .	2324·0	. .	Also a Co line

TABLE of Nickel lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
4	2	2325·5		
2	3	2326·0	2	Also a Co line
4	2	2329·6	2	
6	. .	2330·1	. .	Also a Co line
2	6	2334·1	3	
3*d*	6	2336·2	3	
6	3	2336·6	. .	Also a Co line
6	5	2337·1		
2	. .	2340·7	3	Also a Co line
4	6	2343·0	3	
6	. .	2343·5		
2	3	2344·7	3	Also a Fe line
6	. .	2345·0		
6	4	2346·2	. .	Also a Co line
6	4	2347·6	1	
6*d*	6	2349·8	. .	Also a weak Fe line
6	6	2350·5	. .	Also a Co line
3	3	2355·9	2	
6	3	2358·5	1	
4	6	2366·1	1	Also a Fe line
4	5	2367·0	1	
5	6	2368·9		
4	. .	2369·5		
6	6	2370·9		
2	4	2375·0	2	
6	3	2375·6		
6	6	2378·6		
2	5	2381·8	. .	Also a Co line and a Fe line
6	3	2386·3	1	
3	4	2387·5	1	
4	6	2388·5	1	Also a Fe line
6	6	2388·7		
6	6	2392·0	. .	Also a Co line
4	3	2392·6		
2	2	2394·0	1	Also a Fe line
2	2	2394·3	1	
6	3	2394·7	. .	Also a Fe line
6	. .	2397·2		
6	. .	2400·1	1	Also a Fe line
6	3	2401·7	. .	Also a Co line
6	6	2404·8	1	
6	3	2412·1	1	Also a Co line and an air line
5	3	2412·8		
1*d*	2	2416·0	2	
6	3	2419·0		
6	2	2420·8		
6	3	2423·4		
6	. .	2426·8		
6	. .	2431·2		
4	. .	2433·2	. .	Also a Fe line
6	3	2433·9	. .	Also a Fe line
1*d*	3	2437·5	2	
6	1	2441·5	. .	Also a Fe line

TABLE of Nickel lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
5	. .	2448·1		
6	2	2453·7		
4	6	2455·4		
6	2	2471·8	. .	Also a Fe line
2	3	2472·8	1	Also a Fe line
6	6	2476·6		
3*d*	3	2483·6	1	
6	6	2496·9		
3	. .	2505·9	3	Also a Co line
6	. .	2509·6	2	
1	2	2510·6	3	Also a Co line
6	6	2520·0		
6	. .	2524·1	. .	Close to a Si line
6	3	2539·5		
5	. .	2543·2	1	Also a Fe line
3	3	2545·4	3	
6	6	2549·1	2	
6*d*	4	2552·6	1	Also a Co line
4	. .	2554·7	1	
6	. .	2557·5		
4	5	2559·8	1	
4*d*	. .	2565·7	1	
6	6	2568·2	1	
6	6	2571·7		
4	4	2575·7		
6	6	2579·9	. .	Also a Co line
4	. .	2583·5		
5	. .	2584·4	1	
6	6	2586·7	. .	Also a Co line
5	. .	2593·1	. .	Also a Fe line
6	. .	2600·8	1	
6	. .	2606·1	1	Also a Fe line
6	. .	2606·7	. .	Also a Fe line
3	. .	2609·6	1	
3	. .	2614·9	1	Also a Fe line
6	. .	2626·3	1	
6	. .	2628·4	. .	A doubtful Co line
6	. .	2632·4	1	
6	. .	2636·8		
3	. .	2639·5	1	Also a Fe line
6	. .	2641·0		
6	. .	2643·4		
3	3	2646·8	1	
6	6	2648·6		
3	6	2655·6	1	
5	5	2659·5	1	
6	. .	2664·9		
5	. .	2670·0	. .	Also a Co line and a Fe line
6	. .	2672·1		
6	. .	2674·4		
3	. .	2678·8		
2	. .	2684·0	. .	Also a Co line
6	. .	2690·2		

TABLE of Nickel lines (continued).

Intensity. Spark.	Intensity. Arc.	λ		Remarks.
6	6	2700·4		
5	6	2701·2	..	Also a weak line of Fe
4	4	2708·3		
4	..	2758·7	1	
6	..	2760·4		
4*d*	..	2774·7	2	Also a diffuse line in the Co spark
2	3	2805·0	3	
6*d*	..	2806·0		
6	..	2807·8		
3	1	2820·8		
6	..	2823·9		
2	..	2863·3	1	
..	3	2865·1	..	Also a line in the Co spark
6*d*	..	2880·9	..	} These are perhaps air lines
6*d*	..	2882·2	..	
6	..	2889·1		
6	..	2898·8		
6	..	2900·6		
5	3	2906·9		
2	2	2913·2	1	
6*d*	..	2918·8		
3*d*	..	2928·4	1	Also a Fe line
6	..	2934·3		
2*d*	..	2936·3	1	Also a Fe line
6	6	2938·7	..	Also a Fe line
2	1	2943·5	1	
4	..	2947·1	1	
5*d*	..	2954·5		
6	..	2957·8		
5*d*	..	2968·7		
3	3	2981·2	3	Also a weak Fe line
4	3	2983·6	3	
5*d*	..	2987·7	3	
6	..	2988·0		
3	2	2992·2	3	
3	3	2994·1	3	Also a Fe line
2	2	3002·1	4	
2	2	3003·2	4	
1	1	3011·5	6	
3	..	3018·8	4	
4	4	3031·4		
2	2	3037·5	5	
4	4	3044·5	5	Also a Fe line
2	2	3050·4	4	
2	3	3053·9	6	
2	..	3057·2	6	Also a Fe line
3	3	3064·2	4	
3	3	3080·3	4	
2	..	3086·6	4	
4	..	3096·6	6	
4	..	3098·6	5	
3	3	3101·1	5	
2	2	3101·4	5	

Table of Nickel lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
5	3	3105·0	5	Also a Fe line
5	4	3113·7	6	
1	1	3133·6	6	Also a Fe line
6	6	3134·0	4	
5	4	3145·5	2	
5*d*	5	3158·9	1	
3*d*	3	3179·2	2	
6	. .	3181·2	1	
6	6	3182·6	1	Also a Fe line
6	3	3183·8	1	
6	4	3194·9	4	
3	3	3196·6	4	Also a Fe line
6	. .	3201·5	4	
. .	6	3212·3		
5	. .	3213·7	3	Also a Fe line
6	. .	3216·0		
6	6	3216·6		
5	. .	3217·4	3	
5	5	3221·1	3	
4	4	3224·6	3	
6	6	3226·3	3	
2	1	3232·6	1	Also a Fe line
3	3	3234·2	3	
3	3	3242·6	3	
6	6	3247·8		
4	5	3250·1	3	
6	6	3270·6	1	Also a Fe line
6	. .	3274·4		
5	4	3282·2	6	
6	. .	3290·1	6	
5	6	3311·8	3	Also a Co line
6	. .	3312·4	3	
3	3	3315·1	4	
3	3	3319·7	4	
3	4	3321·6	4	Also a Co line
5	. .	3349·8	3	
6	5	3358·1	2	
3	2	3360·9	3	Also a Co line
5	3	3361·0	3	
4	4	3365·1	3	
4	4	3365·5	3	
6	2	3367·2	1	In explosions of OH with Ni
2	3	3368·9	4	Also a Fe line
3	4	3371·3	4	
3	3	3373·3	3	
6	4	3373·6	2	
4	4	3374·0	4	
1	1	3380·0	4	Also a Co line
2	2	3390·4	3	
2	2	3392·4	4	
6	5	3400·5	2	
6	. .	3402·8	2	
5	6	3404·5	2	Also a Co line

TABLE of Nickel lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
3	3	3406·6	3	
6	5	3409·0	2	
2	2	3412·9	3	
4	1	3413·4	2	In explosions of OH with Ni
1	2	3413·8	4	
6	6	3420·6	1	
1	2	3423·1	4	Also a diffuse Co line
1	1	3433·0	4	Also a Co line
2	2	3436·7	5	Also a Co line
6	. .	3441·6		
1	1	3445·7	4	Also a Co line and in explosions of OH with Ni
1	4	3452·3	3	
5	4	3452·9	2	In explosions of OH with Ni
4	4	3453·5	3	
5*d*	2	3457·7	. .	In explosions of OH with Ni
1	1	3457·9	6	
1	1	3461·1	5	In explosions of OH with Ni
3	2	3465·1	4	Also a Co line
5	5	3466·8	2	
5	4	3468·9	4	
5*d*	6	3470·8	3	
2	2	3471·9	4	
2	2	3483·1	4	
5	5	3485·2	2	
1	1	3492·3	3	In explosions of OH with Ni
2	2	3500·0	3	
5	4	3501·8		
6	5	3505·9		
6	6	3507·3		
1	1	3509·7	4	Also a Co line and in explosions of OH with Ni
2	. .	3513·3	4	Also a Fe line
1	1	3514·4	4	In explosions of OH with Ni
6	. .	3518·0		
3	3	3519·1	1	
1	1	3523·9	2	In explosions of OH with Ni
5	. .	3526·0		
5	6	3527·1	1	Here is a series of fine closely-set lines
6	5	3529·2	1	Also a Co line
6	6	3529·9	1	
3	3	3547·5	2	
6	. .	3550·8	2	
6	. .	3552·8	1	
6	. .	3561·1	2	
1	3	3565·7	3	In explosions of OH with Ni
2	2	3571·2	3	Also a Fe line and in explosions of OH with Ni
2	. .	3576·1	3	
5*d*	5	3587·2	2	
1	1	3597·0	3	In explosions of OH with Ni
5	. .	3601·4	4	
6	6	3608·6	4	
2	2	3609·8	5	
3	3	3612·1	5	In explosions of OH with Ni

TABLE of Nickel lines (continued).

Intensity.		λ		Remarks.
Spark.	Arc.			
1	1	3618·8	5	In explosions of OH with Ni
6	5	3624·1	4	
..	4	3634·9		
..	3	3653·0		
..	6	3655·2		
..	6	3657·5		
..	5	3659·3		
5	..	3663·4	1	
..	6	3666·9		
6	2	3669·7	1	
..	6	3671·5		
5	4	3673·4	1	
6	..	3687·6	1	
..	6	3694·6		
..	6	3697·2		
..	6	3710·9		
3	..	3721·6	1	Also a Fe line
..	6	3724·2		
2	2	3736·1	1	
2	..	3768·9	5	
3	3	3775·0	5	In explosions of OH with Ni
3	4	3783·0	5	In explosions of OH with Ni
2	3	3806·6	3	In explosions of OH with Ni
6	..	3831·7		
5	..	3837·5	2	
5	..	3848·9	2	
2	2	3857·8	7	

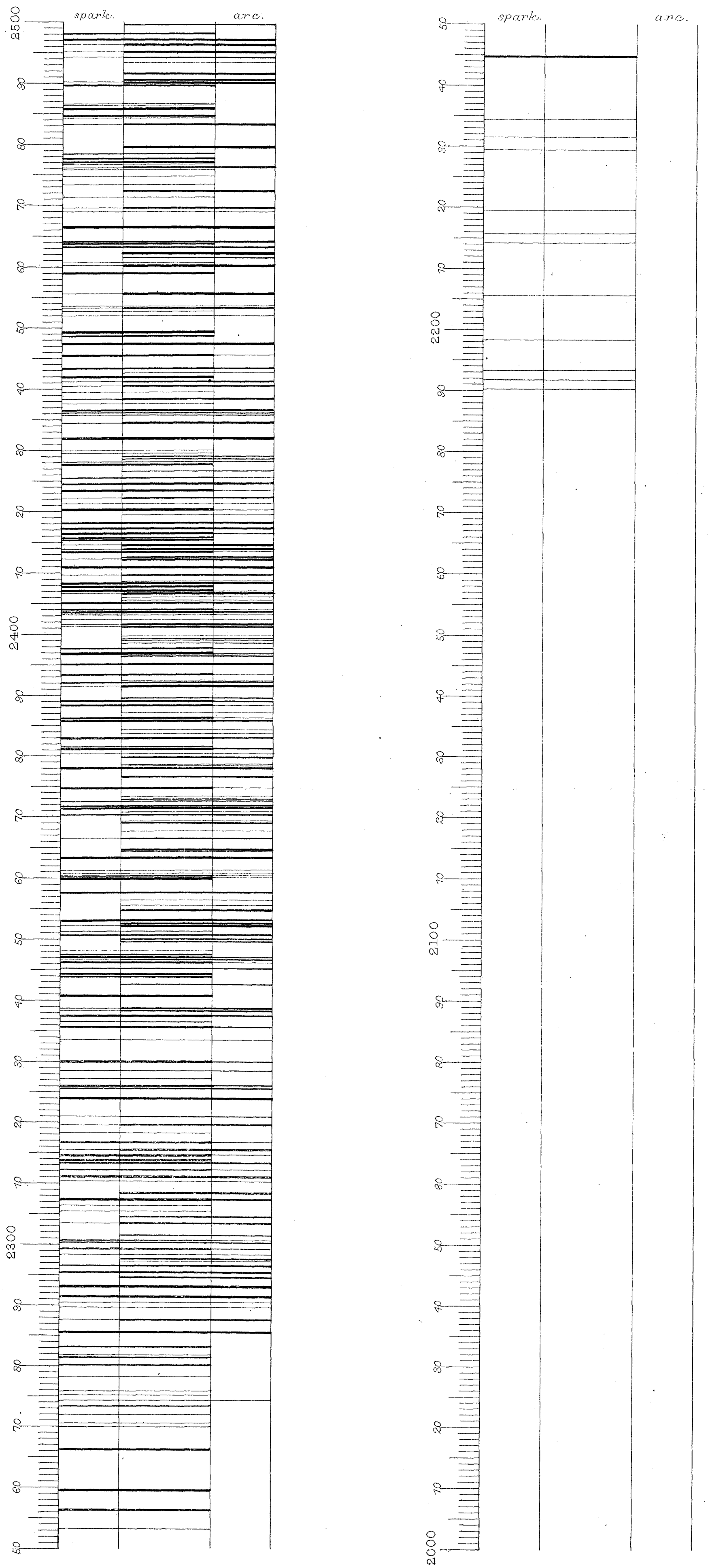
Note on the Maps of the Spectra of Cobalt and Nickel.

These maps contain many lines which are not in the list in the text. These additional lines were observed in the arc between carbon electrodes when metallic cobalt and nickel respectively were introduced into it; but they were not included in the list in the text because the authors were unable, for the reasons given in the text, to be quite sure that they were not due to other metals contained in the carbon electrodes, or in the crucible in which the arc was taken. It is most probable that the greater part are really due to the metals to which they are assigned in the maps.

The reader is referred to the list in the text for the measured wave-lengths, as, owing to a parallactic error in ruling, many of the lines in the maps are placed a fraction of a tenth-meter out of their true places.

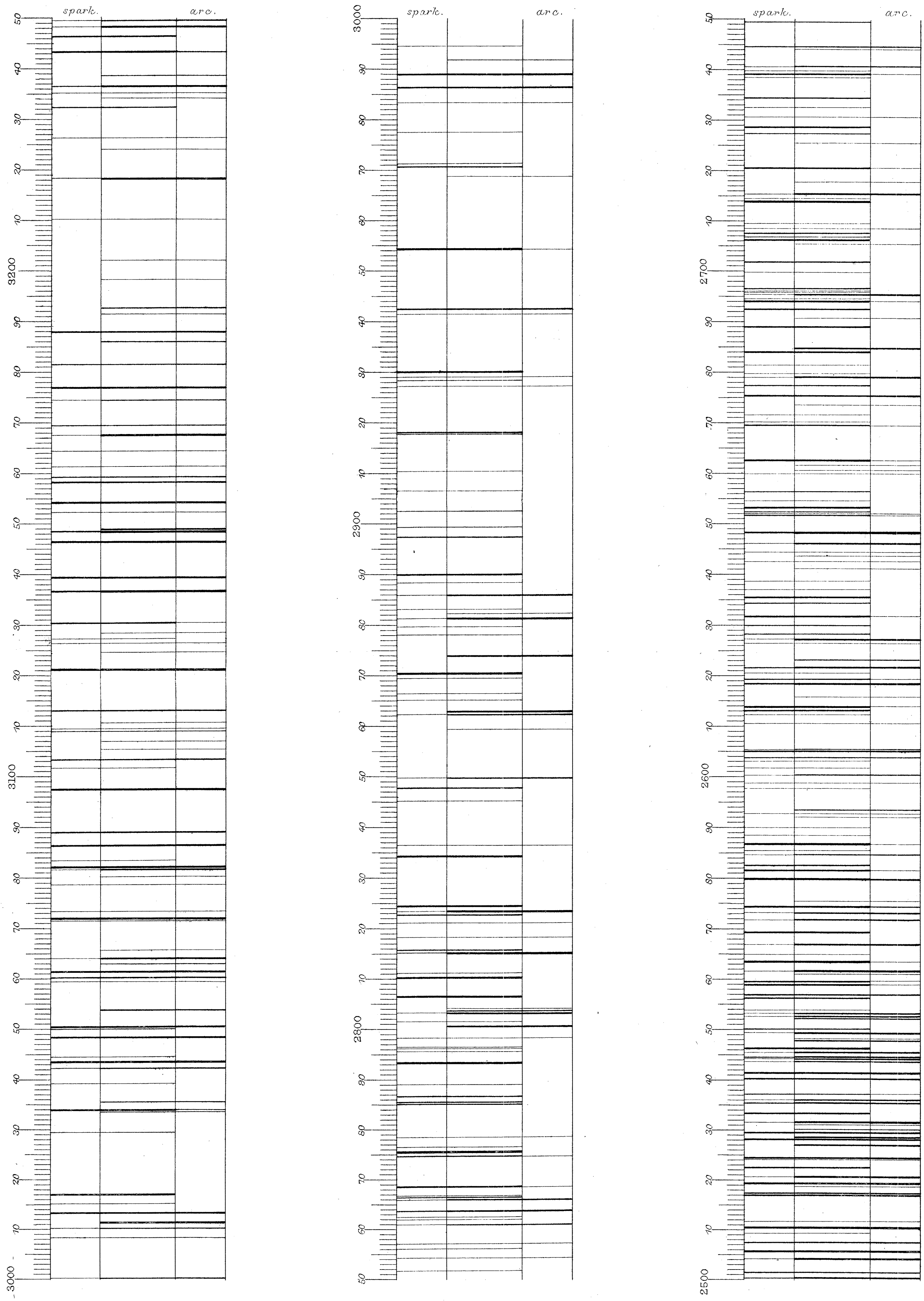
PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Map of the ultra-violet spectrum of Cobalt.



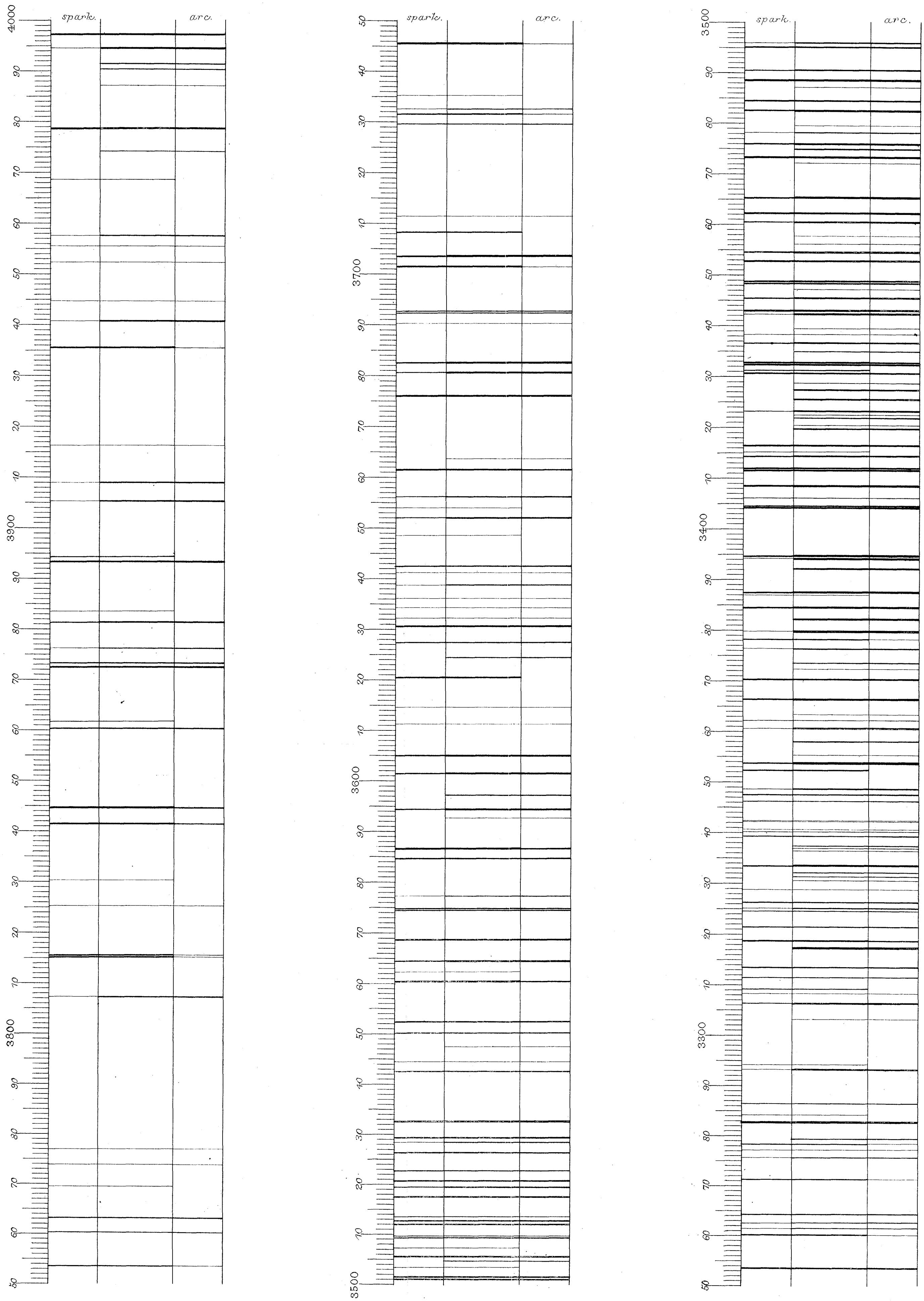
West, Newman & Co sc.

Map of the ultra-violet spectrum of Cobalt.



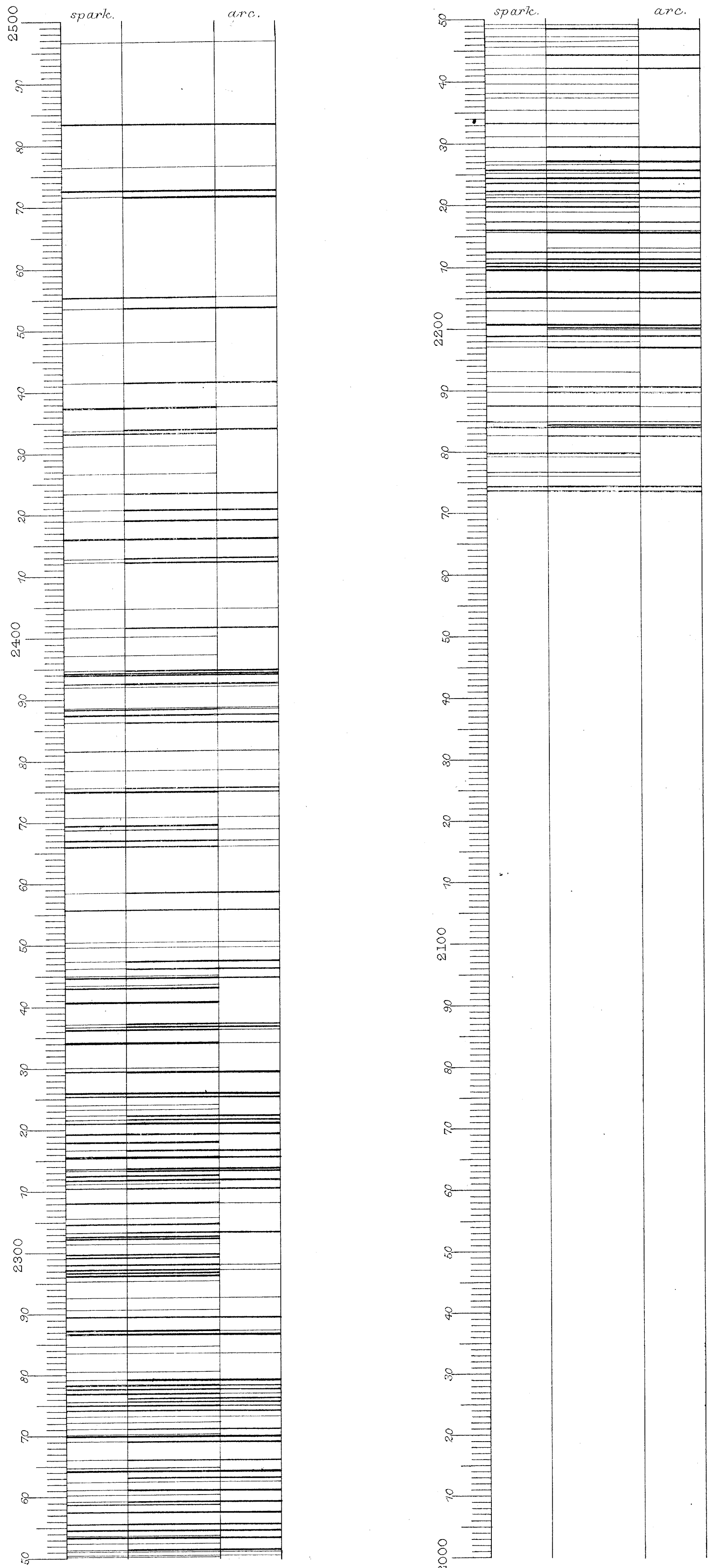
West, Newman & Co. sc.

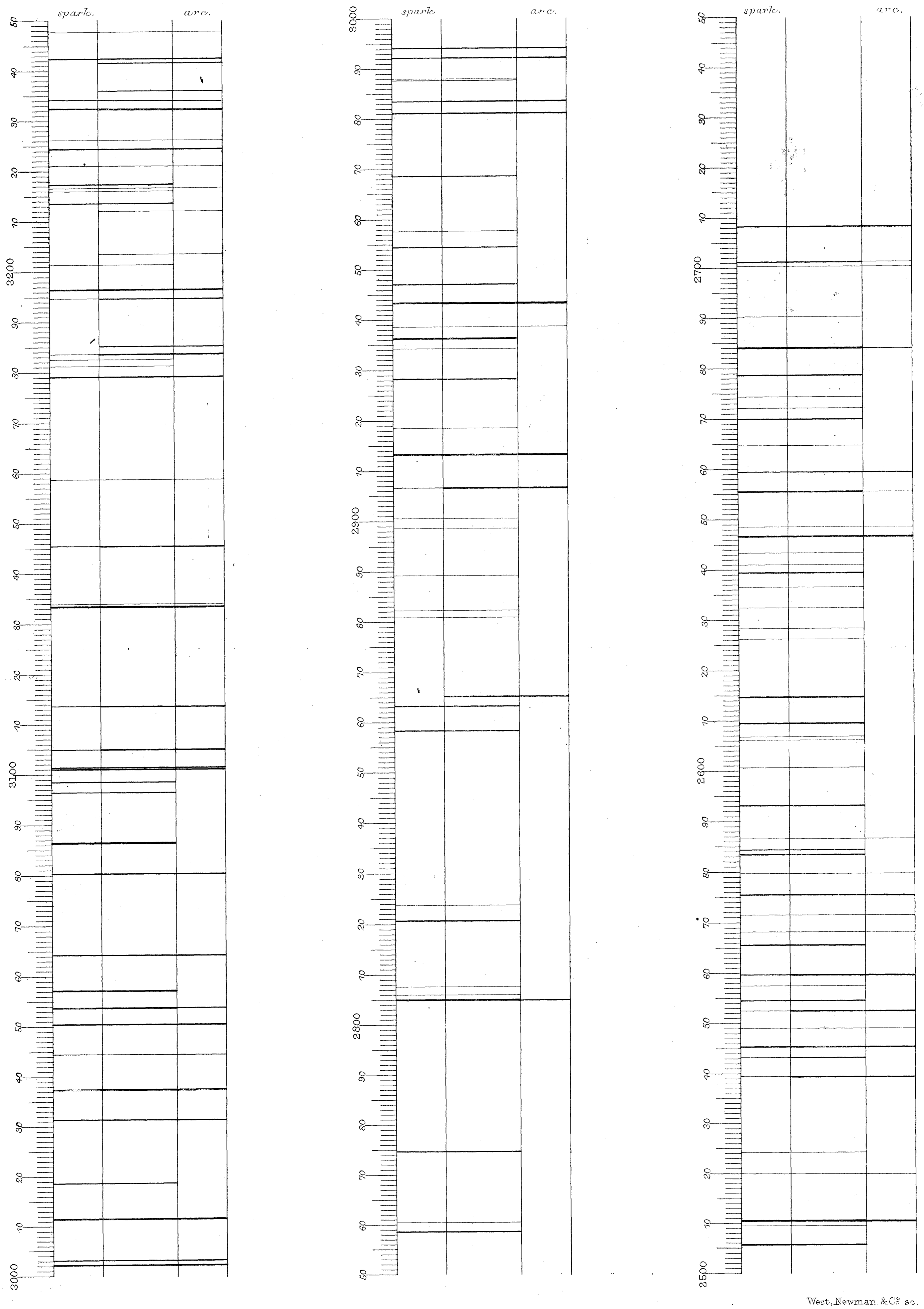
Map of the ultra-violet spectrum of Cobalt.



West, Newman & Co. sc.

Map of the ultra-violet spectrum of Nickel.

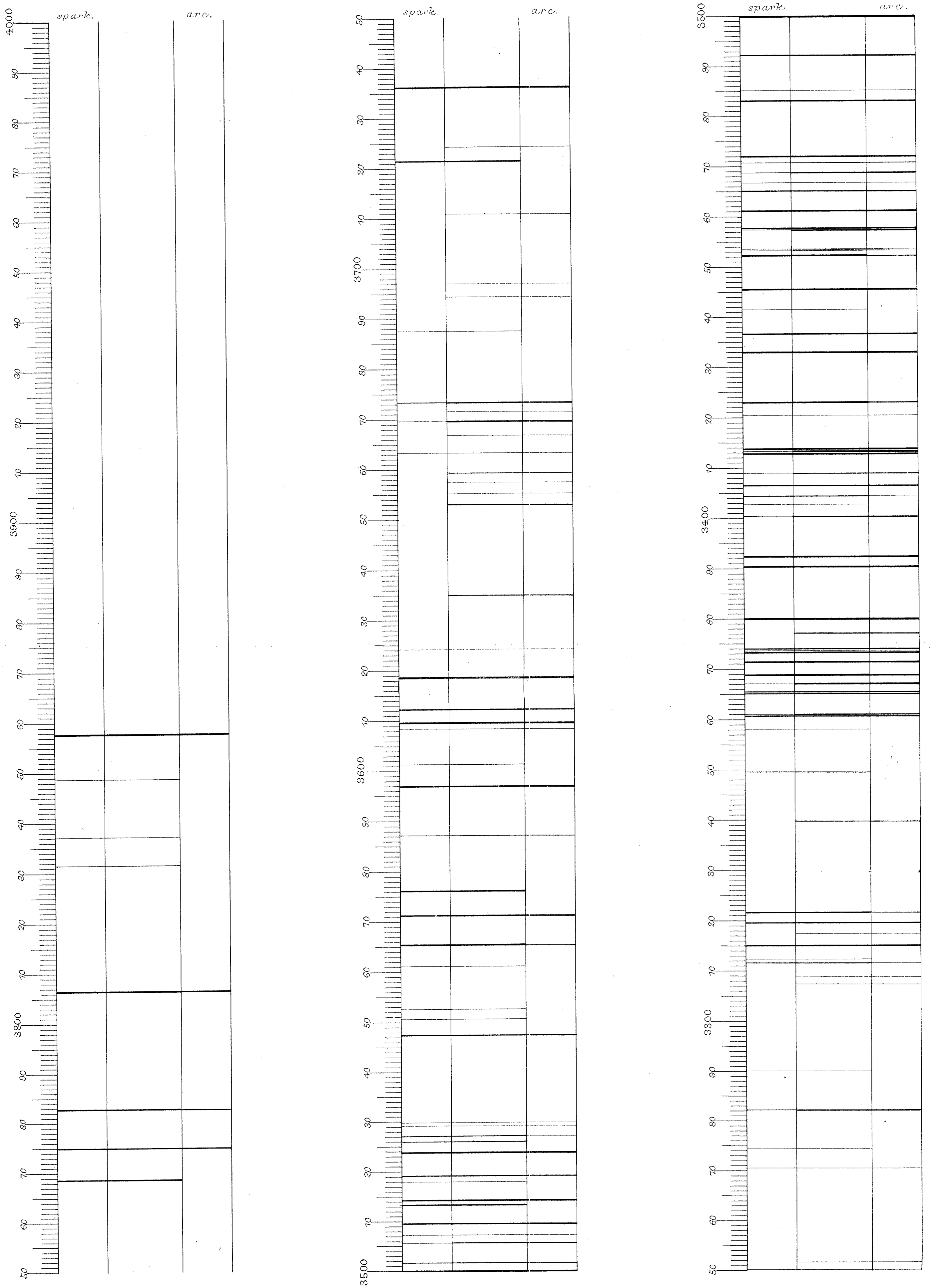




Map of the ultra-violet spectrum of Nickel.

West, Newman & Co. sc.

Map of the ultra-violet spectrum of Nickel.



West, Newman & Co. sc.